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Daily report 15-07-2020

Analysis and prediction of COVID-19 for EU-EFTA-UK and other countries

Situation report 102

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Foreword

The present report aims to provide a comprehensive picture of the **pandemic situation of COVID-19** in the EU countries, and to be able to foresee the situation in the next coming days.

We employ an **empirical model**, verified with the evolution of the number of confirmed cases in previous countries where the epidemic is close to conclude, including all provinces of China. The model does not pretend to interpret the causes of the evolution of the cases but to permit the **evaluation of the quality of control measures made in each state** and a **short-term prediction of trends**. Note, however, that the effects of the measures' control that start on a given day are not observed until approximately 7-10 days later.

The model and predictions are based on two parameters that are daily fitted to available data:

- ✓ *a*: the velocity at which spreading specific rate slows down; the higher the value, the better the control.
- ✓ *K*: the final number of expected cumulated cases, which cannot be evaluated at the initial stages because growth is still exponential.

We show an individual report with 8 graphs and a table with the **short-term predictions** for different countries and regions. We are adjusting the model to **countries and regions** with at least 4 days with more than 100 confirmed cases and a current load over 200 cases. The **predicted period** of a country depends on the number of datapoints over this 100 cases threshold, and is of 5 days for those that have reported more than 100 cumulated cases for 10 consecutive days or more. For short-term predictions, we assign higher weight to last 3 points in the fittings, so that changes are rapidly captured by the model. The whole methodology employed in the inform is explained in the last pages of this document.

In addition to the individual reports, the reader will find an initial dashboard with a brief analysis of the situation in EU-EFTA-UK countries, some summary figures and tables as well as **long-term predictions** for some of them, when possible. These long-term predictions are evaluated without different weights to data-points. We also discuss a specific issue every day.

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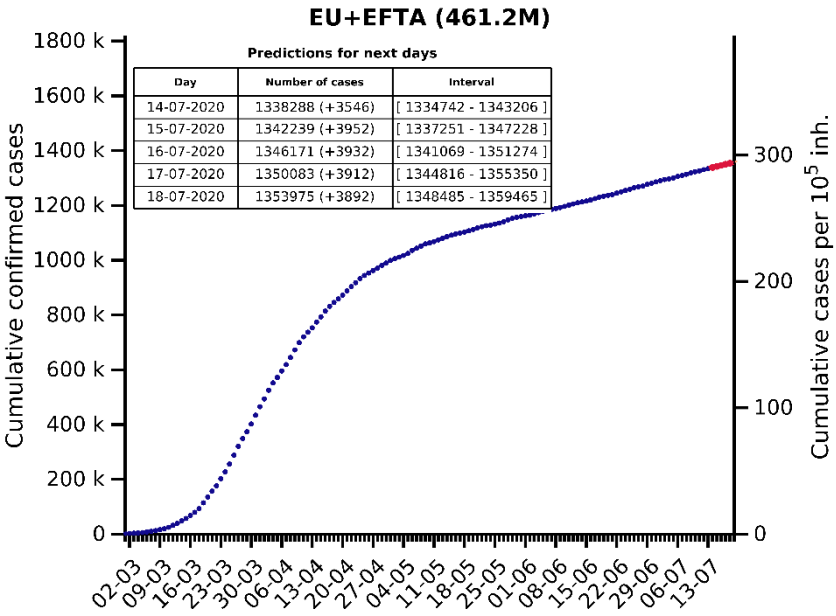
(0) Executive summary – Dashboard

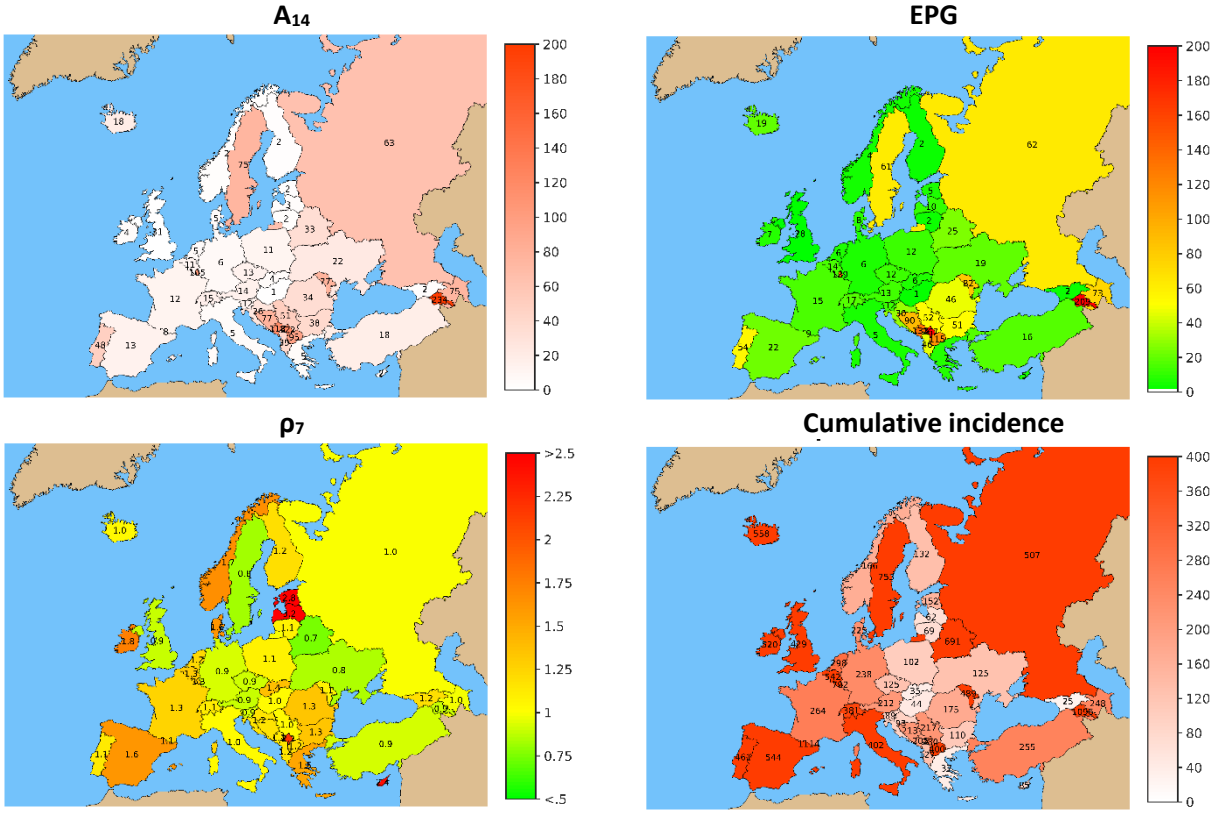
Situation and highlights

Romania is clearly experiencing a second wave. If the peak of the first wave reached a level of 400 daily new cases, they are now at the level of 600 without signs of control. Nevertheless, its current relative incidence is at degree 5 in the Biocom-Cov2 scale, which is lower than in some countries that are already in the tail. **Bulgaria** and **Croatia** are also in a similar situation, but with lower absolute number of cases.



Other countries are showing new local outbreaks that are perceived at the country level but that are lower than first wave. The relative importance of these outbreaks depend on the regions' capacity for controlling them. If we look at their Biocom-Cov2 degree, we see that new outbreaks have pushed **Luxembourg** upt to degree 7, **Portugal** to 6, **Switzerland**, **Czech Republic** and **Austria** to 3. **Sweden** remains at an uncertain situation, with a Biocom-Cov2 degree equal to 6 but a ρ_7 below 1 for the last week.

Last weeks, there are some countries that show many gaps on data (Spain, France, Denmark and Sweden, among others), most of these gaps corresponding to weekends. These gaps make the automatic analyses very difficult with current methodology, if they persist the whole methodology should be revised.



Situation and trends per country

Table of current situation in EU countries. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) form worst (red) situations according to each of the variables. Last column (**EPG_{EST}**) is assessed with **estimated real 14-day attack rate** (see report from 22/04 for details). **EPG_{REP}** is calculated with **data reported by countries**. EPG_{REP} and EPG_{EST} **cannot be compared between them** because scales are different, but can be independently used for estimating risk of countries according to reported or estimated real situation, respectively. **Data from 2nd July.**

	Reported data								Indexes			
Country	Cumulative cases	Attack rate /10^5 inh.	Cumulative deaths	Mortality /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	Estimated active cases (last 14 days)	Estimated 14-day attack rate /10^5 inh.	ρ_7 (1)	EPG_{REP} (2)	EPG_{EST} (3)	Biocom-Cov degree
Spain	255,953	552.2	28,406	61.3	6,682	14.4	74,477	158.4	1.63	23	257	3
Italy	243,344	409.5	34,984	58.9	2,766	4.7	39,629	65.5	1.03	5	67	2
Germany	199,726	243.8	9,071	11.1	5,001	6.1	23,271	27.8	0.92	6	26	2
France	172,377	266.3	30,029	46.4	7,576	11.7	133,485	204.5	1.25	15	256	3
Sweden	76,001	772.5	5,545	56.4	7,550	76.7	56,186	556.3	0.82	63	455	6
Belgium	62,781	552.7	9,787	86.2	1,272	11.2	19,816	171.0	1.31	15	224	3
Netherlands	51,091	300.8	6,128	36.1	818	4.8	9,887	57.7	1.22	6	71	2
Portugal	47,051	453.6	1,668	16.1	4,910	47.3	17,981	176.3	1.12	53	198	6
Poland	38,457	100.6	1,588	4.2	4,064	10.6	17,117	45.2	1.08	11	49	3
Romania	33,585	169.8	1,931	9.8	6,615	33.4	42,287	219.8	1.34	45	295	5
Switzerland	32,931	384.3	1,687	19.7	1,300	15.2	6,648	76.8	1.11	17	85	3
Ireland	25,670	543.2	1,746	36.9	197	4.2	1,367	27.7	1.75	7	49	2
Austria	19,060	218.8	709	8.1	1,283	14.7	5,143	57.1	0.89	13	51	3
Czech Republic	13,341	125.7	355	3.3	1,387	13.1	4,064	37.9	0.90	12	34	3
Denmark	13,061	228.7	610	10.7	293	5.1	1,394	24.1	1.62	8	39	2
Norway	8,984	167.4	253	4.7	119	2.2	337	6.2	1.66	4	10	1
Bulgaria	7,645	107.2	283	4.0	2,656	37.2	13,006	187.2	1.34	50	251	5
Finland	7,301	132.7	329	6.0	87	1.6	379	6.8	1.19	2	8	1
Luxembourg	4,956	860.4	111	19.3	657	114.1	1,632	260.7	1.32	151	345	7
Hungary	4,263	43.7	595	6.1	108	1.1	1,556	16.1	1.02	1	16	1
Greece	3,883	34.7	193	1.7	474	4.2	2,558	24.5	1.52	6	37	2
Croatia	3,827	90.8	120	2.8	1,050	24.9	3,980	97.0	1.16	29	113	4
Estonia	2,015	153.6	69	5.3	26	2.0	NA	NA	2.80	6	NA	2
Slovakia	1,908	35.0	28	0.5	241	4.4	NA	NA	1.38	6	NA	2
Iceland	1,905	523.0	10	2.7	63	17.3	NA	NA	1.03	18	NA	3
Lithuania	1,875	64.5	79	2.7	58	2.0	NA	NA	1.08	2	NA	2
Slovenia	1,859	89.5	111	5.3	259	12.5	1,687	81.2	0.92	12	75	3
Latvia	1,178	59.8	31	1.6	60	3.0	NA	NA	3.19	10	NA	2
Cyprus	1,022	87.4	19	1.6	24	2.1	NA	NA	2.43	5	NA	2
Malta	674	157.1	9	2.1	4	0.9	NA	NA	NA	NA	NA	1
Liechtenstein	85	220.5	1	2.6	2	5.2	NA	NA	NA	NA	NA	0

Scale											
Worst	Worst	Worst	Worst	Worst	Worst	Worst	Worst	Worst	2.0	100	1000
Best	Best	Best	Best	Best	Best	Best	Best	Best	0.0	0	0

Disclaimer: estimated active cases and estimated 14-day attack rate are assessed by assuming a lethality of 1 % (see report from 20 to 24 April, #37-41). This value can change in countries where suspicious deaths are reported as well (real values would be lower) and in countries where incidence among elderly people was minor (real values would be higher)

(1) ρ_7 is the average of 7 consecutive ρ, but can still fluctuate. (2,3) EPG stands for Effective Growth Potential. EPG_{REP} is the product of attack-rate of last 14 days per 10^5 inhabitants by ρ_7 (empiric reproduction number). EPG_{EST} is the product of estimated real attack-rate of last 14 days per 10^5 inhabitants and ρ_7. Biocom-Cov degree is an epidemiological situation scale based on the level of last week's mean daily new cases (https://upcommons.upc.edu/handle/2117/189661, https://upcommons.upc.edu/handle/2117/189808).

Analysis: Different measurements of epidemics speed propagation. On the meaning of a basic reproductive number in a non-disperse epidemics.

We find that one of the main drawbacks in characterizing the epidemic outbreaks is the importance given to the basic reproductive number as if it were a characteristic value of each type of disease. It is not correct to talk about R_0 as being something inherently characteristic of the disease and the way it is transmitted**. Many circumstances modulate the number of people who will become infected when the spread begins.** The basic reproductive number (R_0) depends on the number of susceptible people, as Kermack and McKendrick deduced, but it also depends on how they behave, population density and mobility, among others. The Covid-19 epidemic has been a good example of R_0 being too ambiguous. R_0 may only be of interest in recurrent epidemics such as influenza, where the number of susceptible people and their behavior can be considered similar from one year to the next. Trying to overcome this problem, **we propose here that another approach to measure velocity of propagation would be clearer**.

Epidemiology and microbiology are two of the disciplines related to biological systems where mathematics has been used normally for many decades. A common challenge for both is to measure the growth rate of the system and the causes that determine it.

- In microbiology we have two extremes. In industrial production, we need the growth rate to be as high as possible, whereas in food security we need the speed to be as low as possible. Today, the physical and chemical factors that determine the growth rate of crops are very well known.
- In epidemiology we need to be able to objectively measure the rate of disease spread, as well as to know the factors that determine the magnitude of that rate.

Most microbiological systems of industrial or biomedical interest are quite complex, although they are often characterized by a known or limited composition. Variables like temperature and pH, among others, are very well controlled. Contrarily, biological systems that suffer from epidemics and pests tend to be much more complex and difficult to define and control. For example, microbial culture systems are often performed in a bioreactor or in containers where space is a not too important variable, while the spread in space is one of the most important factors in epidemiology. Nevertheless, microbiology and epidemiology are two areas of knowledge that are conceptually close from the point of view of mathematics, which is why it can be very useful to take advantage of solutions from one of the fields to solve problems in the other discipline.

Let us recall here the specific growth rate in microbiology:

$$\mu = \frac{1}{m}\frac{dm}{dt}$$

Here, m is the biomass (or any other quantitative variable). $\frac{dm}{dt}$ is the velocity at which biomass is produced. Finally, its division by the biomass results on the velocity of biomass production per each unit of mass, i.e., the *specific* growth rate. We can try now to translate this strategy of using the specific framework in epidemiology. We can mimic the former definition and test if this specific rate could be useful to describe the pandemic. Following this epidemiological strategy, we can define the **specific propagation rate** as:

$$\mu = \frac{1}{N}\frac{dN}{dt}$$

Given that in epidemics the basic unit of time is a day, we must use finite differences and not derivatives. Therefore, the proper definition for the specific velocity should read

$$\mu = \frac{1}{N}\frac{\Delta N}{\Delta t}$$

where **N are the active cases** (i.e, those cases with the ability to transmit the disease). In this epidemic, active cases can be represented by the variable A_{14},, i.e., the cumulative incidence of last 14 days).

If μ is small, the number of active cases will decrease over time. If it is large it will increase. We can deduce for **which specific rate threshold value the number of active cases remains constant in the case of Covid-19**. Consider now the limit of epidemic control where the daily number of new cases is always the same, ΔN, in which case the number of active cases is $N = 14\ \Delta N$

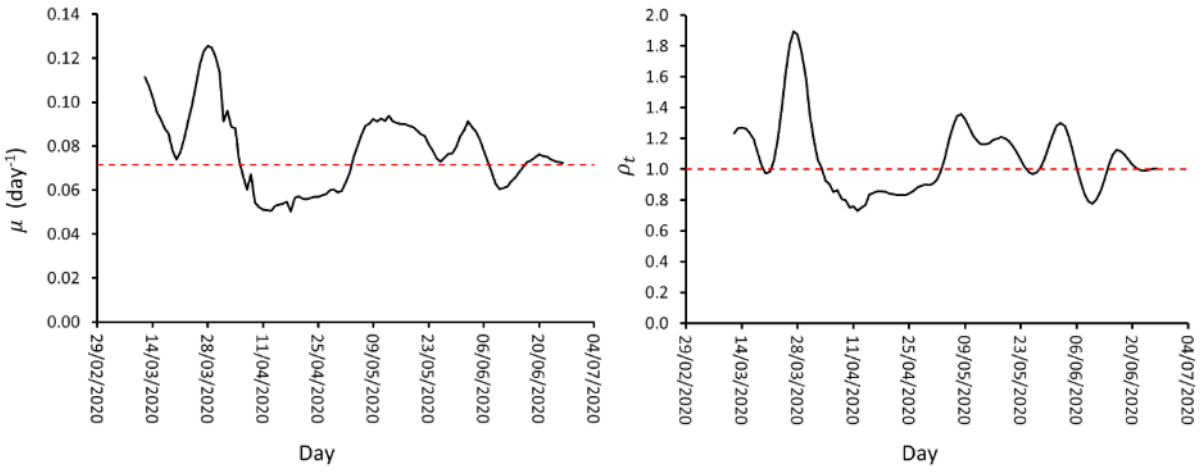
Therefore:

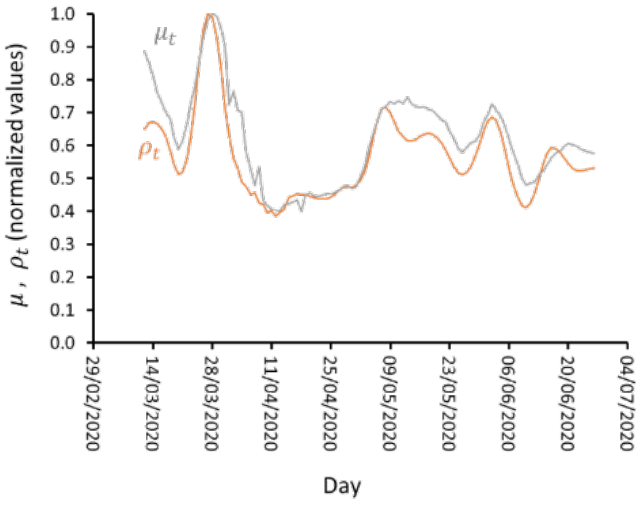
$$\mu = \frac{1}{N}\frac{\Delta N}{\Delta t} = \frac{1}{14\,\Delta N}\frac{\Delta N}{\Delta t} = \frac{1}{14\,\Delta t} = \frac{1}{14\ \cdot\ 1\ day} = 0.07143\ day^{-1}$$

In other words, now the control limit is not 1, like in R_0 or in R_t, but roughly 0.07.

In epidemiology, the reproduction number is usually used to assess the speed of propagation, the basic reproduction number or the specific reproduction number is used. These are concepts that emerged with the first mathematical models, such as the SIR of Kermack and McKendrick of the early twentieth century. We will see that the **reproduction number is indeed a good tool to measure the speed of spread of the disease and instead is not a good tool to talk about the number of people who infect each infectious person**.

We use the empirical reproductive rate (ρ_t) by quoting the average of three three-day new cases divided by the three-day average of new cases five days earlier. To perform the following calculations, we performed a 7-day run average on the list of new cases, in order to decrease oscillations and the weekend effect. In the following figures we represent the two magnitudes for the evolution we have had in Iran.





We see how the behavior of μ and ρ_t are very similar, we see especially in the third plot (bottom) where we draw the two parameters normalized to 1. We can say, in fact as everyone knows, that the reproductive number is excellent indicator of the speed of spread of the epidemic.

The other interpretation of the reproductive number, on the other hand, is not at all appropriate and leads to many errors. Mathematically, the number can be interpreted as the average number of new cases caused by each infectious person. However, this is problematic. The first is to think that the reproductive number is indicative of how the infection is spreading, as if each person is more or less infecting the value found. In the case of Covid-19, and clearly in many other epidemics, **we have people and circumstances who transmit with very high values and people who do so with very low values**. In this case, **the distribution and interpretation are much more interesting than the average value.**

Situation and trends in other countries

Table of current situation in a sample of non-EU countries. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) form worst (red) situations according to each of the variables. EPG_{REP} and EPG_{EST} **cannot be compared between them** because scales are different, but can be independently used for estimating risk of countries according to reported or estimated real situation, respectively. **Data from 2nd July.**

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Country	Cumulative cases	Attack rate /10^5 inh.	Cumulative deaths	Mortality /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	Estimated active cases (last 14 days)	Estimated 14-day attack rate /10^5 inh.	ρ_7 [1]	EPG_{REP} [2]	EPG_{EST} [3]	Biocom-Cov degree
United States of America	3.431.574	1.036,7	136.466	41,2	797.142	240,8	3.543.785	1.070,6	1,16	279	1.240	9
Brazil	1.926.824	906,5	74.133	34,9	524.783	246,9	2.140.756	1.007,1	1,03	254	1.035	9
India	936.181	69,2	24.309	1,8	350.688	25,9	1.036.642	76,6	1,15	30	88	4
Russia	739.947	507,0	11.614	8,0	92.098	63,1	NA	NA	0,99	62	NA	6
Peru	333.867	1.012,6	12.229	37,1	48.654	147,6	195.987	594,4	1,00	147	592	8
Chile	319.493	1.671,3	7.069	37,0	40.100	209,8	96.831	506,5	0,90	189	456	8
Mexico	311.486	241,6	36.327	28,2	85.397	66,2	1.070.325	830,1	1,01	67	838	6
Iran	262.173	312,1	13.211	15,7	34.511	41,1	180.188	214,5	0,93	38	199	5
Pakistan	255.769	115,8	5.386	2,4	42.299	19,1	92.129	41,7	0,83	16	35	3
Saudi Arabia	237.803	683,1	2.283	6,6	46.980	134,9	51.516	148,0	0,83	113	123	7
Canada	108.475	287,4	8.798	23,3	4.282	11,3	36.411	96,5	1,07	12	104	3
Qatar	104.533	3.628,3	150	5,2	8.445	293,1	NA	NA	0,82	240	NA	9
Argentina	103.252	228,5	1.926	4,3	38.735	85,7	79.766	176,5	1,63	140	287	7
Ecuador	69.570	394,3	5.130	29,1	13.138	74,5	110.388	625,7	1,12	83	701	6
Belarus	65.269	690,7	474	5,0	3.151	33,3	NA	NA	0,74	25	NA	4
	Scale											
	Worst	Worst	Worst	Worst	Worst	Worst	Worst	Worst	2,0	100	1000	
	Best	Best	Best	Best	Best	Best	Best	Best	0,0	0	0	

Disclaimer: estimated active cases and estimated 14-day attack rate are assessed by assuming a lethality of 1 % (see report from 20 to 24 April, #37-41). This value can change in countries where suspicious deaths are reported as well (real values would be lower) and in countries where incidence among elderly people was minor (real values would be higher).

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Time indicators by country

These tables summarize a few time indicators for each country: time since 50 cases were reported, time interval between an attack rate of $1/10^5$ inhabitants and an attack rate of $10/10^5$ inhabitants, and time interval between attack rates of 10 to 100 per 10^5 inhabitants (only for countries that have overtaken this threshold). **Data from 2nd July.**

EU+EFTA+UK countries

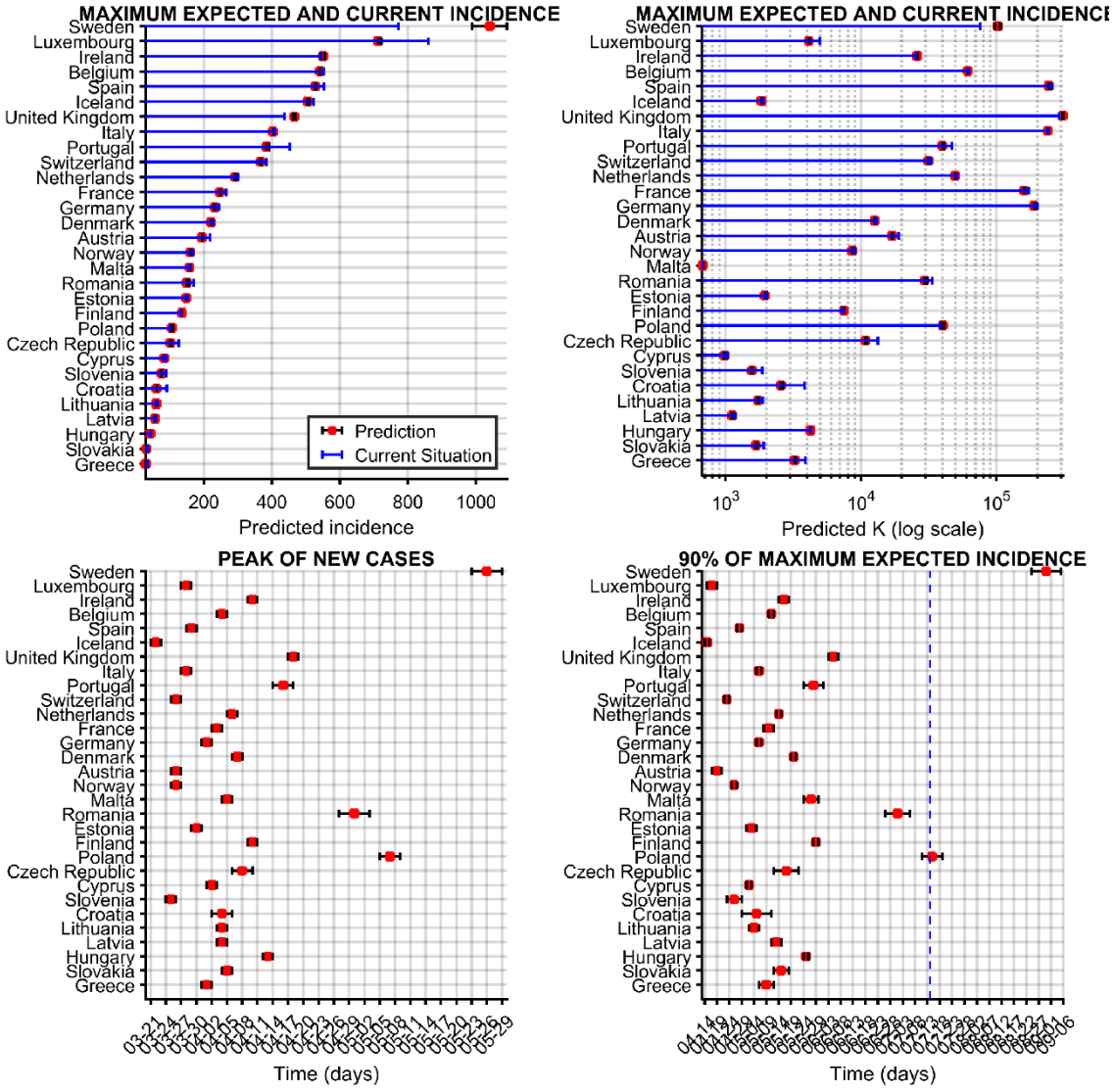
Countries	Days since the first 100 cases	Time interval between 1 and 10 cases / 10^5 inh. (days)	Time interval between 10 and 100 cases / 10^5 inh. (days)
Italy	143	11	16
Germany	137	12	17
France	136	10	20
Spain	136	8	12
Belgium	133	10	15
United Kingdom	132	10	12
Netherlands	131	11	20
Sweden	131	10	28
Norway	131	2	7
Switzerland	131	8	11
Austria	129	10	14
Denmark	128	4	30
Czech Republic	125	11	94
Finland	125	12	46
Greece	125	18	NA
Iceland	125	5	15
Portugal	124	9	15
Slovenia	124	6	NA
Estonia	123	5	30
Ireland	123	8	18
Poland	123	17	NA
Romania	123	15	66
Luxembourg	120	6	7
Slovakia	119	24	NA
Bulgaria	118	30	88
Croatia	118	12	NA
Hungary	117	20	NA
Latvia	117	12	NA
Lithuania	116	9	NA
Malta	115	9	35
Cyprus	114	12	NA

Other countries

Countries	Days since the first 100 cases	Time interval between 1 and 10 cases / 10^5 inh. (days)	Time interval between 10 and 100 cases / 10^5 inh. (days)
Iran	140	11	42
United States of America	135	8	15
Canada	126	11	27
Qatar	126	3	31
Brazil	123	20	34
Saudi Arabia	122	21	29
Chile	121	13	36
Pakistan	121	35	59
India	121	38	NA
Russia	120	15	24
Peru	120	18	22
Ecuador	120	10	30
Mexico	119	25	47
Argentina	118	39	54
Belarus	107	10	18

Long-term predictions

Evaluated with the **whole historical series**. Up-left: Predictions of maximum incidences per country **at the end of the first wave** (total final expected attack rate per 10^5 inh.). Up-right: Predictions of maximum absolute number of cases per country at the end of the first wave (K, in log scale). Blue lines indicate current situation. Bottom-left: Time in which peak in new cases was achieved / will be achieved. Bottom-right: Time at which 90 % of K was achieved / will be achieved. Blue dotted line indicates current date.



Final expected value for EU+EFTA+UK as a whole is not shown any more, since we are in the tail (see Analysis section in Report #87, https://upcommons.upc.edu/handle/2117/190497).

Situation and trends in Italian and Spanish regions

Italy

Data from **15th July**

	Reported data								Indexes			
Country	Cumulative cases	Attack rate /10^5 inh.	Cumulative deaths	Mortality /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	Estimated active cases (last 14 days)	Estimated 14-day attack rate /10^5 inh.	ρ_7 (1)	EPG_{REP} (2)	EPG_{EST} (3)	Biocom-Cov degree
Lombardia	95.236	948,4	16.765	167,0	1.226	12,2	21.610	214,8	0,91	11	196	3
Piemonte	31.515	723,4	4.118	94,5	150	3,4	1.967	45,2	0,75	3	34	2
Emilia Romagna	28.989	650,1	4.271	95,8	481	10,8	7.073	158,6	1,08	12	171	3
Veneto	19.441	396,3	2.043	41,6	152	3,1	1.560	31,8	1,59	5	51	2
Toscana	10.338	277,2	1.127	30,2	84	2,3	915	24,5	0,65	1	16	1
Liguria	10.042	647,6	1.561	100,7	60	3,9	947	61,0	1,18	5	72	2
Lazio	8.376	142,5	847	14,4	257	4,4	2.643	45,0	1,24	5	56	2
Marche	6.805	446,2	987	64,7	19	1,2	268	17,6	2,47	3	43	1
Trento	4.881	455,2	405	37,8	17	1,6	137	25,4	0,79	1	20	2
Campania	4.787	82,5	432	7,4	88	1,5	826	14,2	0,75	1	11	1
Puglia	4.541	112,7	547	13,6	11	0,3	126	3,1	NA	NA	NA	1
Friuli Venezia Giulia	3.339	274,8	345	28,4	27	2,2	282	23,2	0,86	2	20	1
Abruzzo	3.331	254,0	467	35,6	42	3,2	581	44,3	1,54	5	68	2
Sicilia	3.115	62,3	283	5,7	34	0,7	292	5,8	1,77	1	10	1
Bolzano	2.677	2.491,7	292	271,8	35	32,6	394	75,5	2,69	87	203	3
Umbria	1.452	164,6	80	9,1	11	1,2	NA	NA	1,48	2	NA	1
Sardegna	1.376	83,9	134	8,2	10	0,6	93	5,7	1,21	1	7	1
Calabria	1.218	62,6	97	5,0	37	1,9	NA	NA	3,00	6	NA	2
Valle d'Aosta	1.196	952,2	146	116,2	1	0,8	12	9,7	0,00	0	0	0
Molise	446	145,9	23	7,5	1	0,3	NA	NA	0,43	0	NA	1
Basilicata	405	72,0	27	4,8	3	0,5	NA	NA	0,43	0	NA	0

Scale											
Worst	Worst	Worst	Worst	Worst	Worst	Worst	Worst	Worst	2,0	100	1000
Best	Best	Best	Best	Best	Best	Best	Best	Best	0,0	0	0

Spain

Data from 6th July. Symptoms onset date.

	Reported data				Indexes		
Autonomous regions	Cumulative cases	Attack rate /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	ρ_7 (1)	EPG_{REP} (2)	Biocom-Cov degree
Madrid	72,578	1,092.9	547	8.2	1.05	9	2
Catalunya	60,214	795.9	3,424	45.3	1.3	58	6
Castilla y Leon	26,760	1,111.3	124	5.1	1.07	6	2
Castilla-La Mancha	22,542	1,107.4	197	9.7	0.88	8	3
Andalucia	17,154	203.6	360	4.3	1.51	6	2
Comunitat Valenciana	15,117	303.9	213	4.3	1.22	5	2
Euskadi	14,833	681.0	222	10.2	2.00	20	3
Galicia	10,997	407.2	237	8.8	0.91	8	3
Navarra	8,048	1,238.2	142	21.8	2.98	65	5
Aragon	7,502	568.0	653	49.4	1.70	84	6
Extremadura	5,830	547.2	162	15.2	2.55	39	4
La Rioja	4,021	1,282.3	26	8.3	4.05	34	3
Murcia	2,555	171.7	69	4.6	1.77	8	2
Canarias	2,535	114.9	36	1.6	1.45	2	2
Asturias	2,442	238.9	7	0.7	2.14	1	1
Baleares	2,395	201.6	49	4.1	0.98	4	2
Cantabria	2,367	406.9	14	2.4	1.11	3	2
Ceuta	222	261.7	0	0	NA	NA	0
Melilla	141	166.4	1	1.2	NA	NA	2

Scale						
Worst	Worst	Worst	Worst	2.0	200
Best	Best	Best	Best	0.0	0

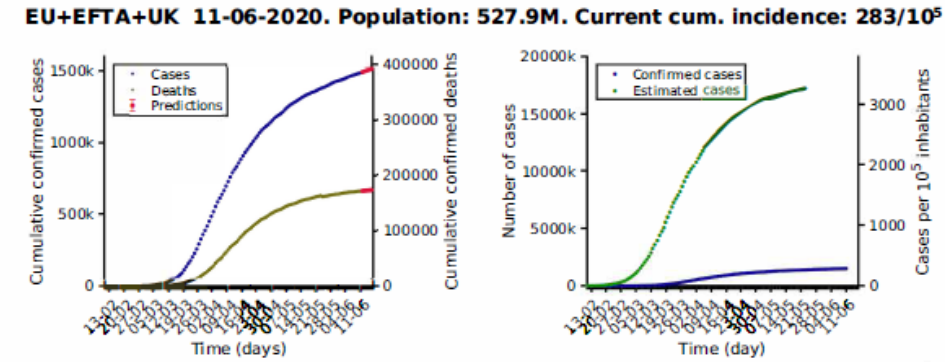
Disclaimer: estimated active cases and estimated 14-day attack rate are assessed by assuming a lethality of 1 % (see report from 20 to 24 April, #37-41). This value can change in countries where suspicious deaths are reported as well (real values would be lower) and in countries where incidence among elderly people was minor (real values would be higher).

(1) ρ_7 is the average of 7 consecutive ρ, but can still fluctuate. (2,3) EPG stands for Effective Growth Potential. EPG_{REP} is the product of attack-rate of last 14 days per 10^5 inhabitants by ρ_7 (empiric reproduction number). EPG_{EST} is the product of estimated real attack-rate of last 14 days per 10^5 inhabitants and ρ_7. Biocom-Cov degree is an epidemiological situation scale based on the level of last week's mean daily new cases (https://upcommons.upc.edu/handle/2117/189661, https://upcommons.upc.edu/handle/2117/189808).

Long-term predictions are not shown any more, since all Italian and Spanish regions are already in the tail (see Analysis section in Report #87, https://upcommons.upc.edu/handle/2117/190497).

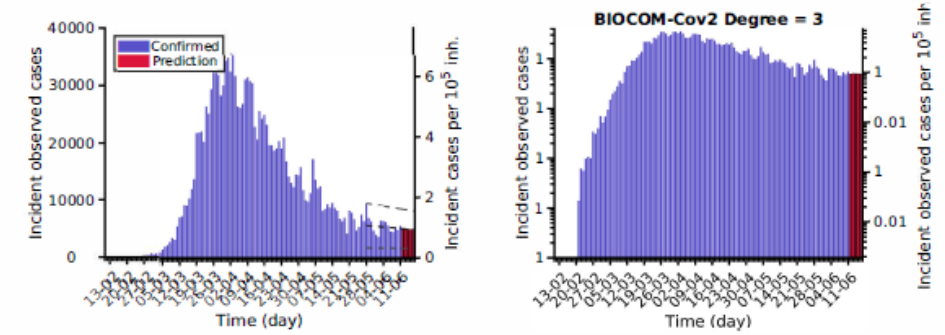
Legend: Countries' reports details

Reported cumulative cases (blue) and deaths (brown), together with predictions (red



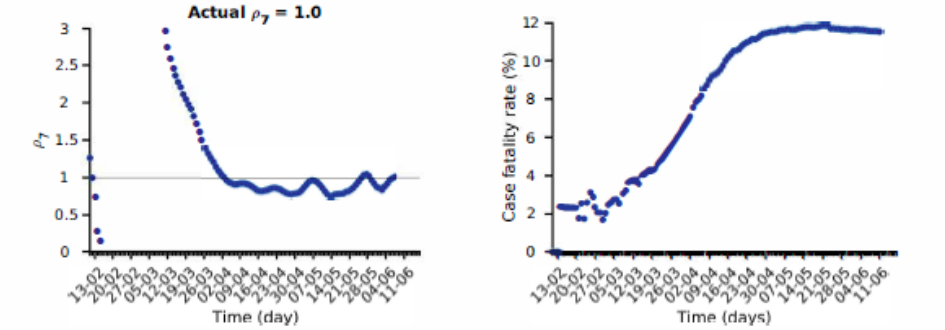
Estimated and reported cases.

Incident observed cases and predictions.



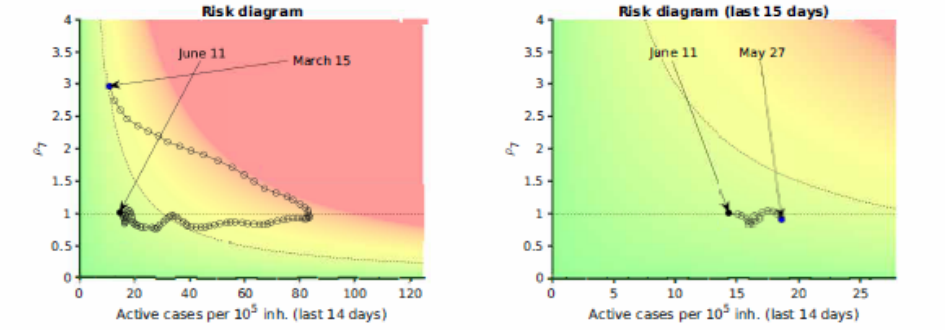
Incident observed cases in a logarithmic scale, with Biocom-Cov degree.

Evolution of empiric reproductive number ρ_7



Case fatality rate

Risk diagram

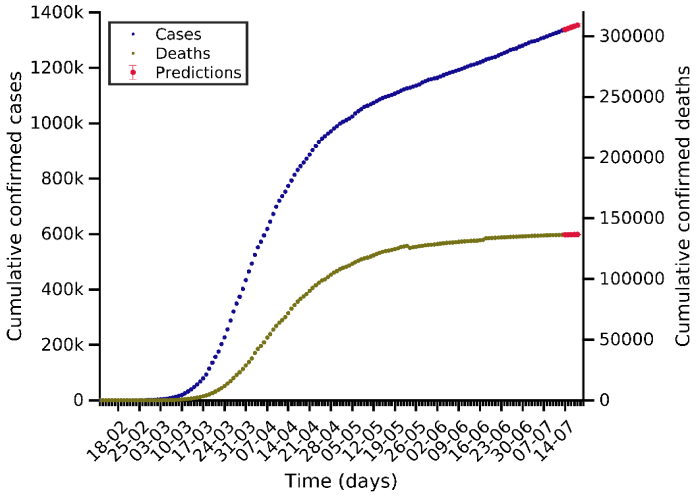


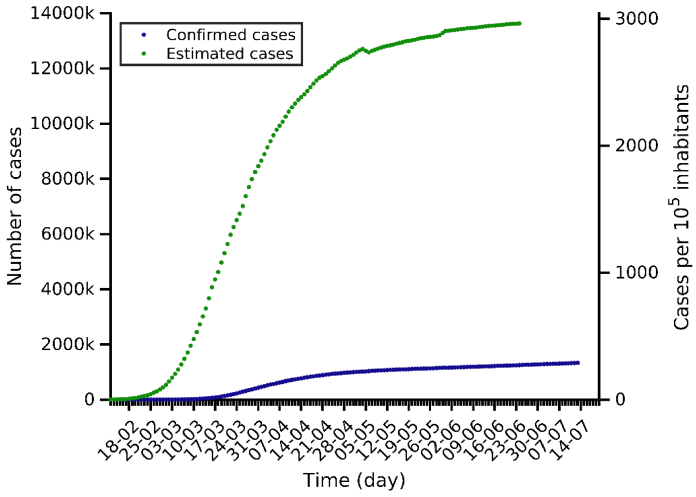
Risk diagram of last 15 days

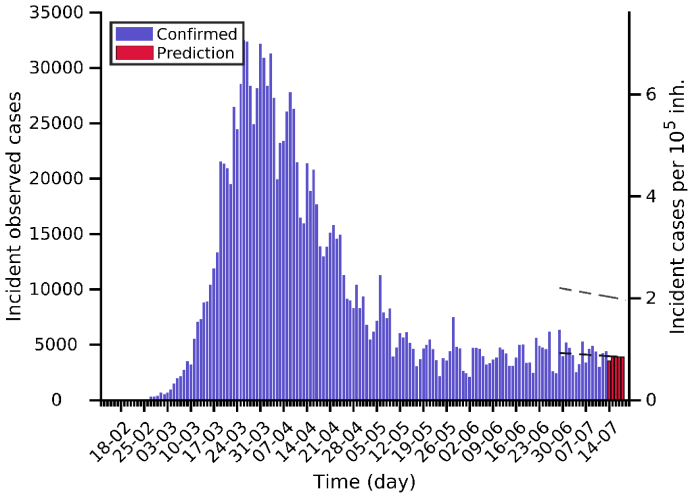
(1) Analysis and prediction of COVID-19 for EU+EFTA+UK

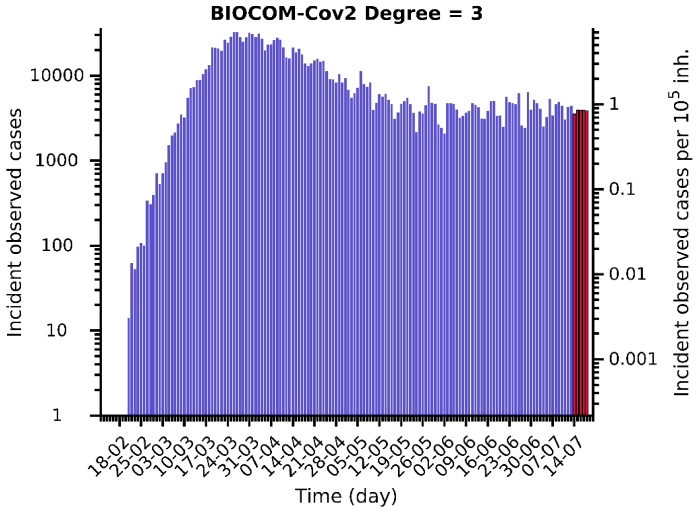
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

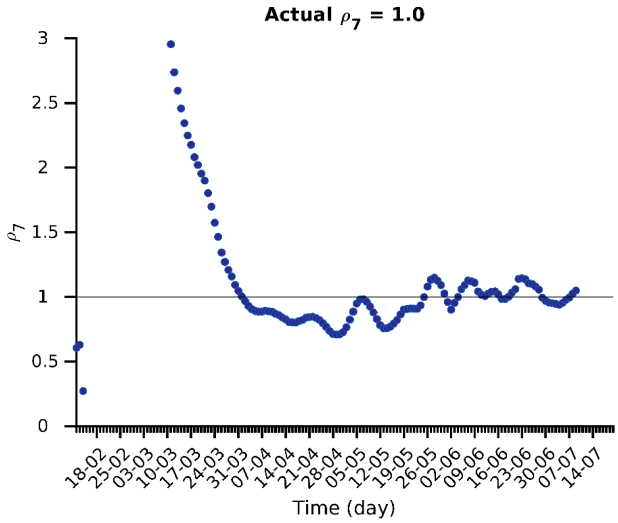
EU+EFTA 14-07-2020. Pop: 460.0M. Cumulative incidence: 290/10⁵

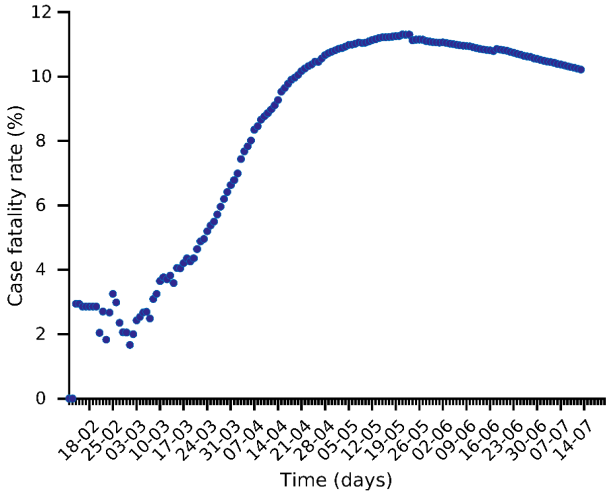


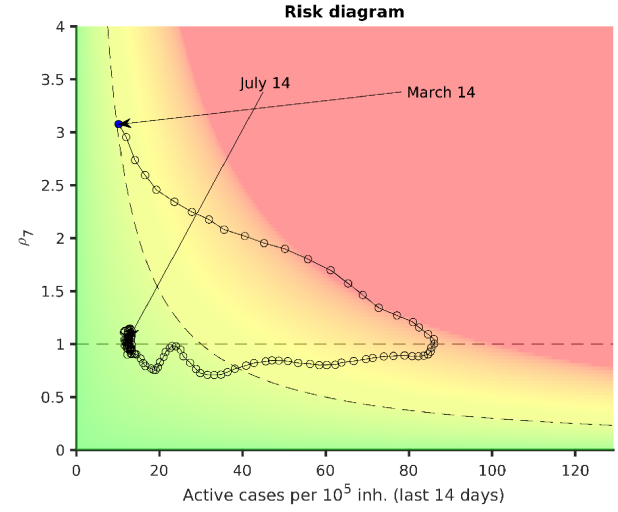


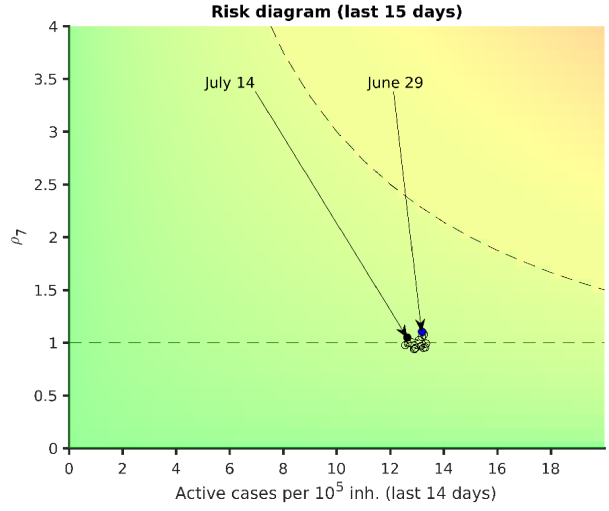




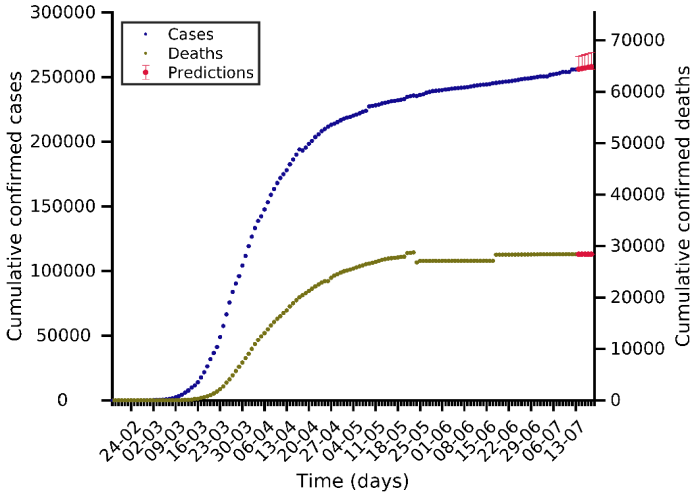


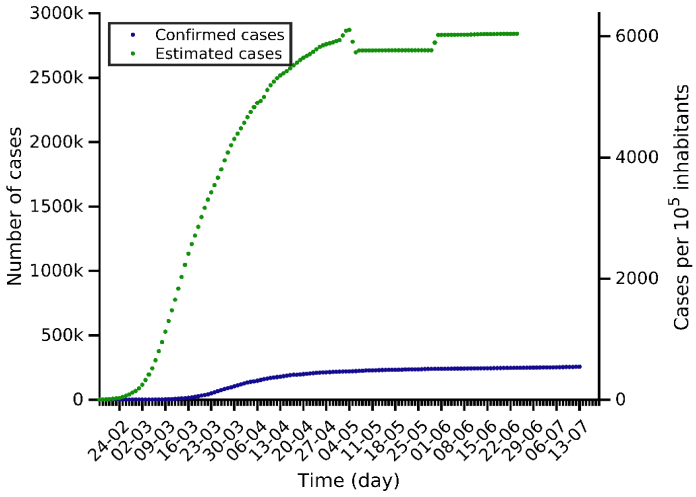


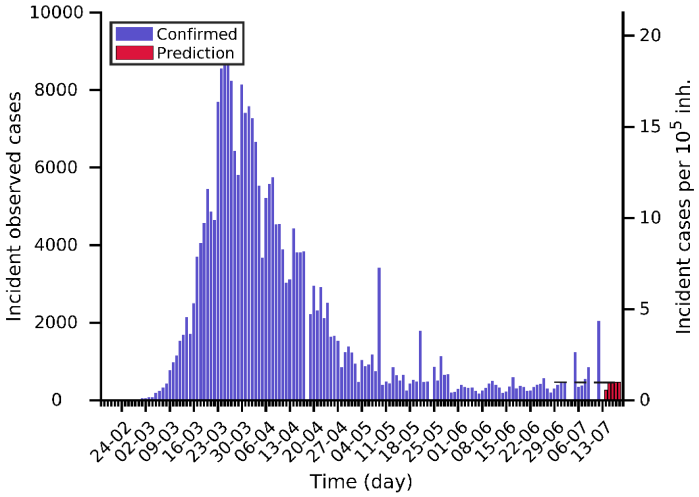


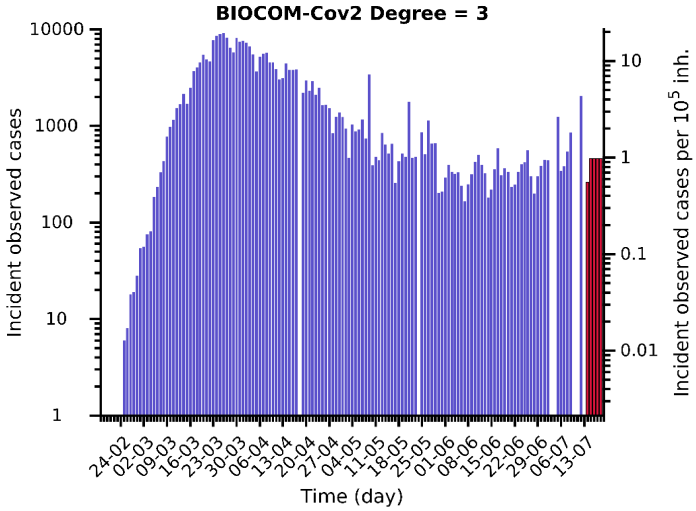


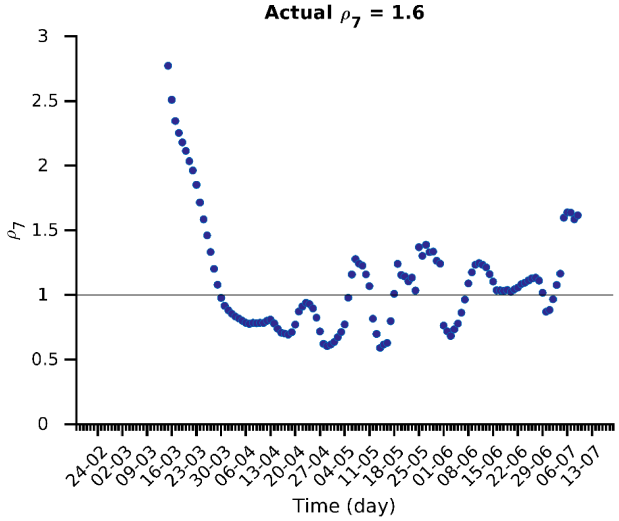
Spain 13-07-2020. Pop: 47.0M. Cumulative incidence: 544/10⁵

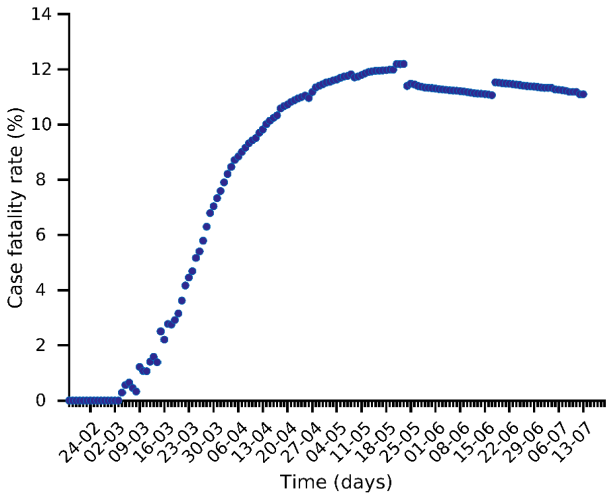


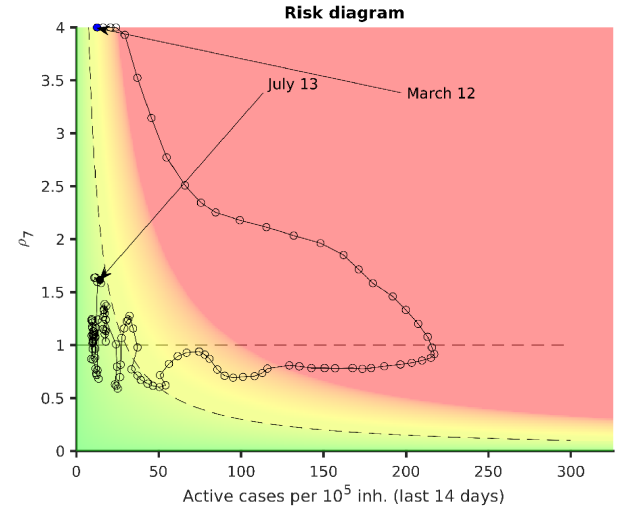


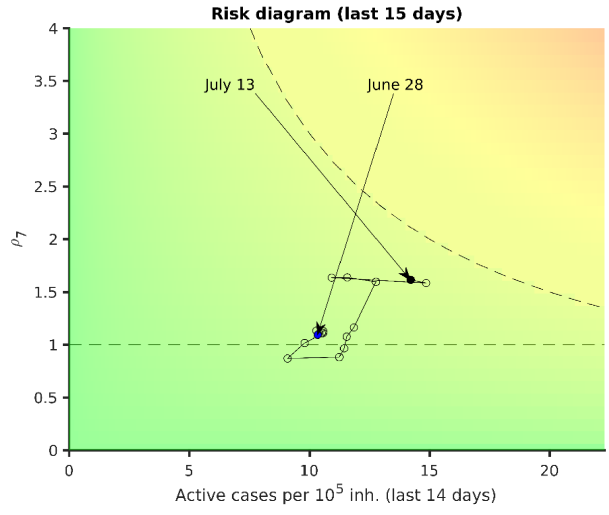




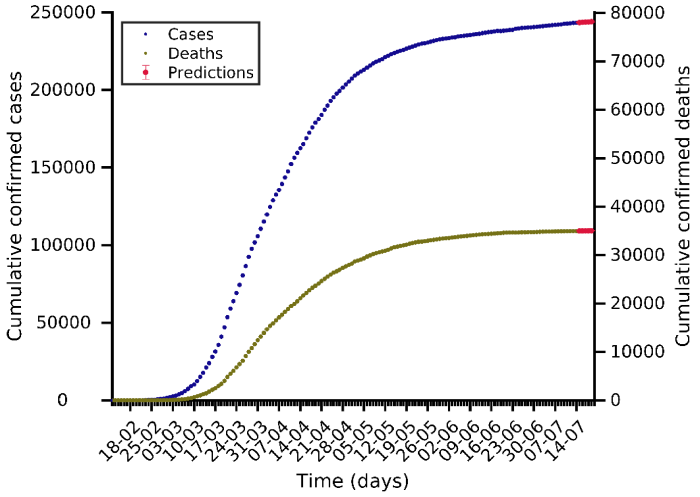


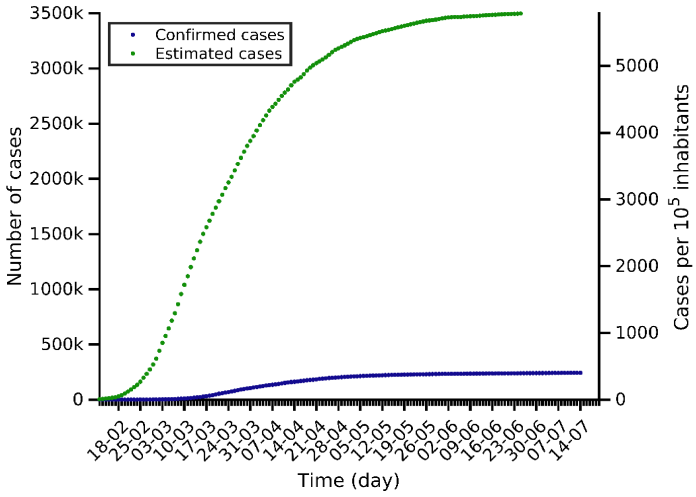


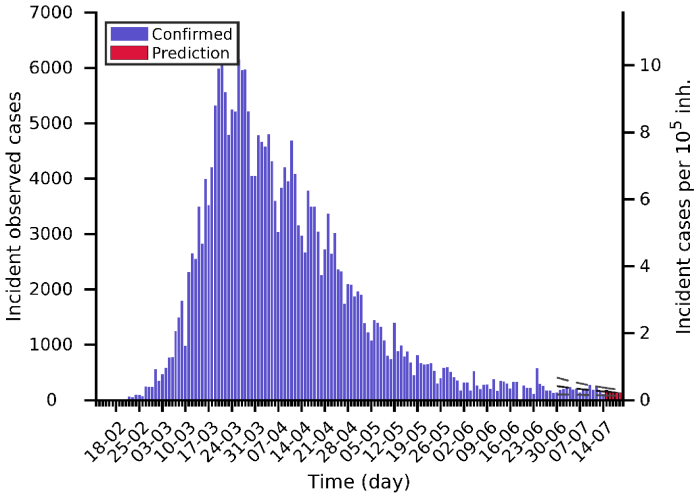


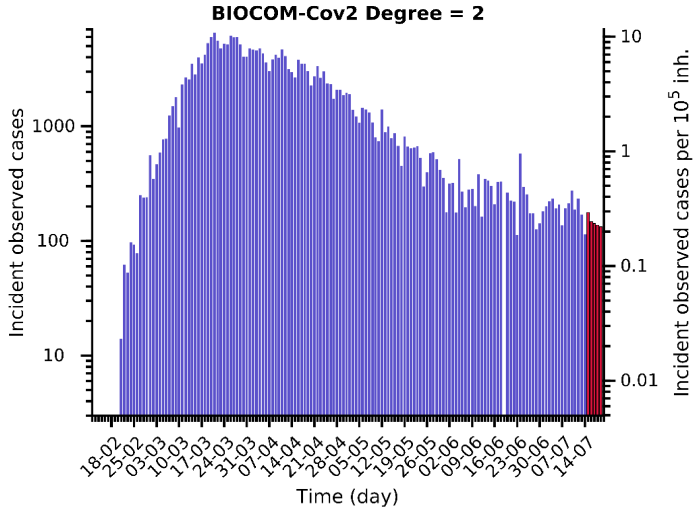


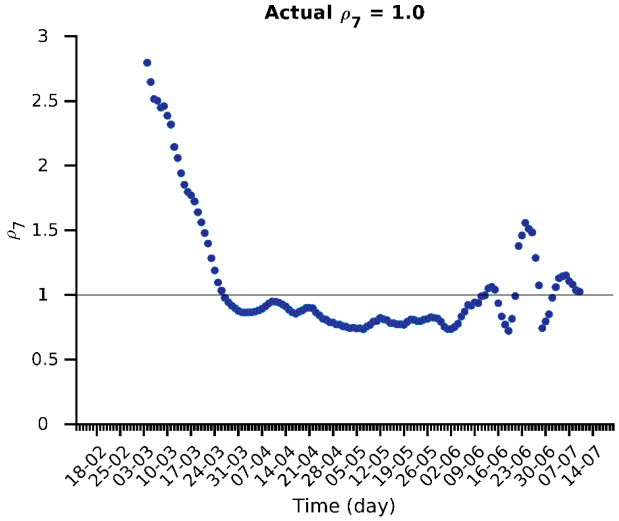
Italy 14-07-2020. Pop: 60.5M. Cumulative incidence: 402/10⁵

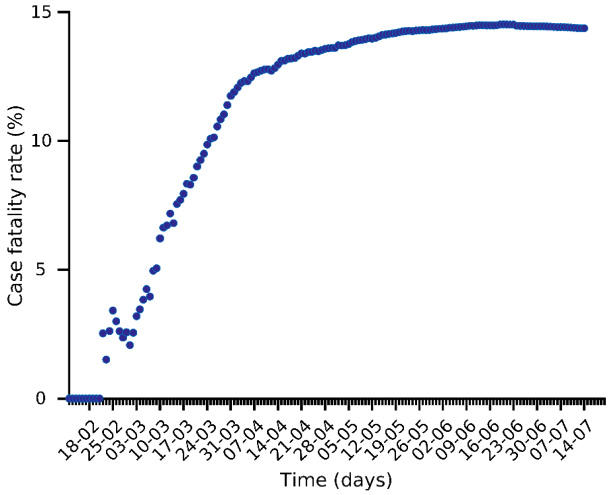


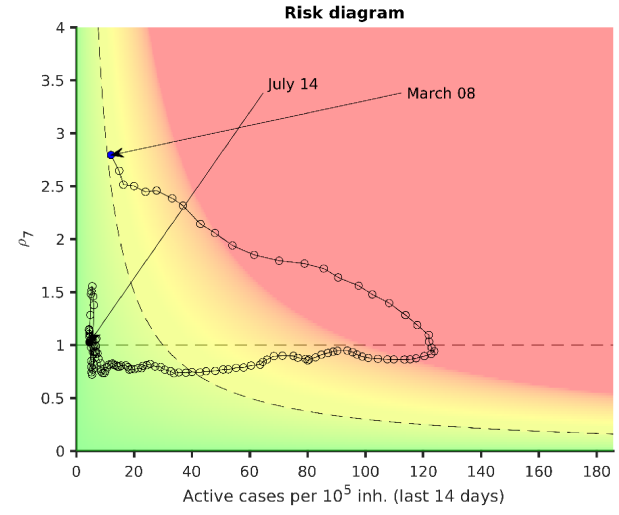


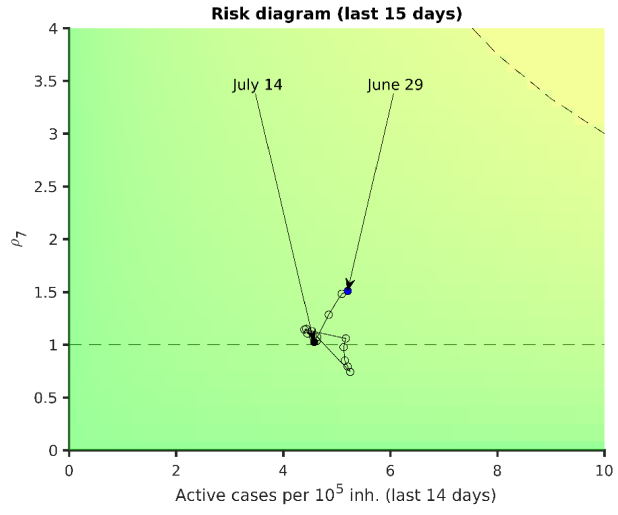




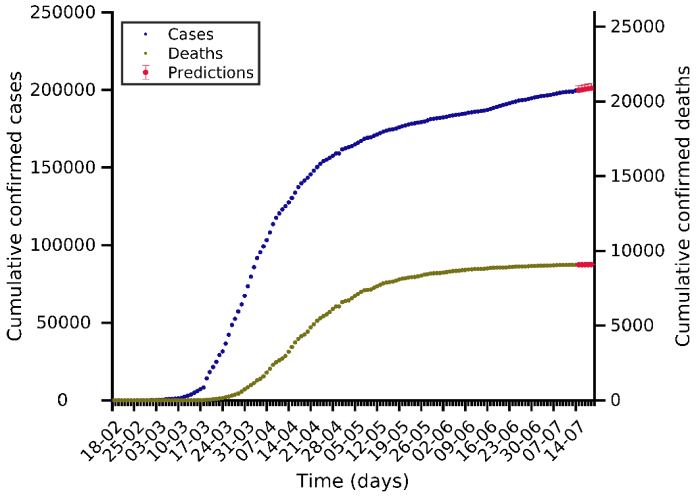


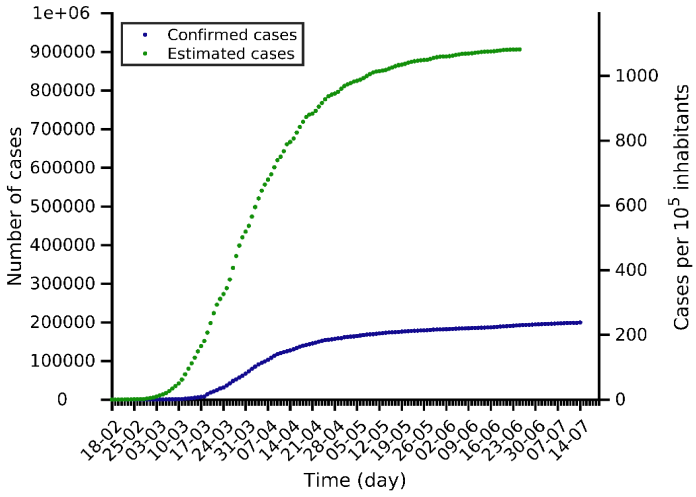


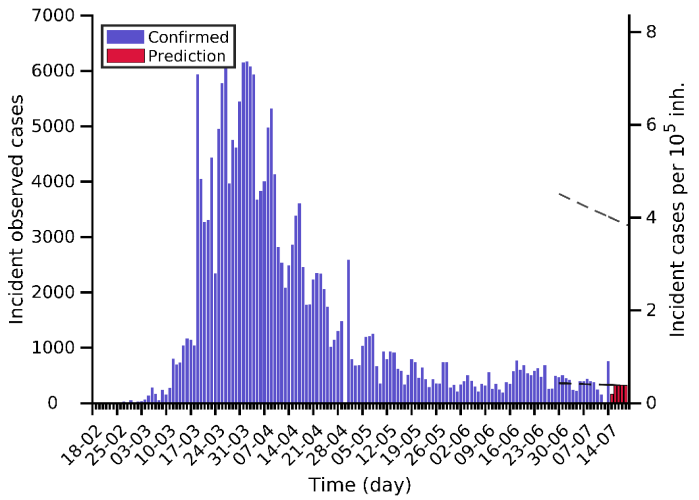


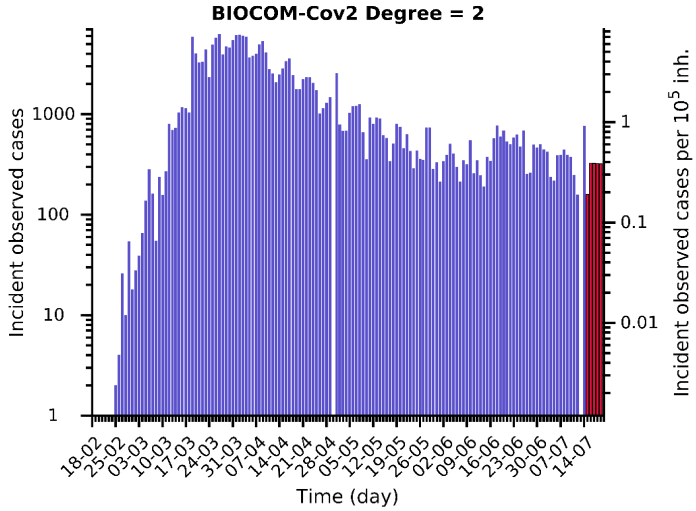


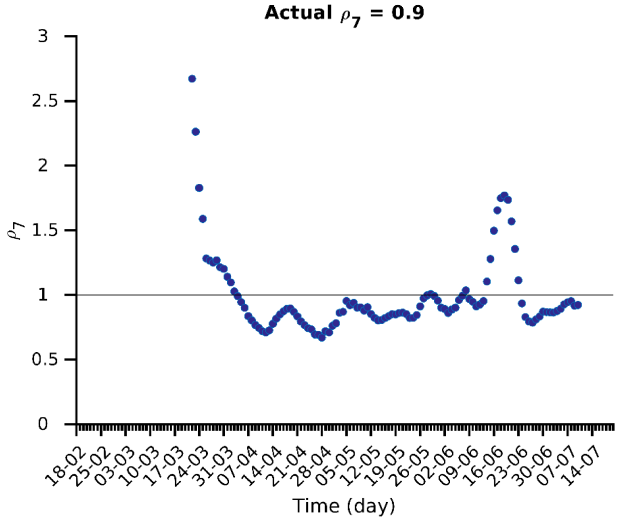
Germany 14-07-2020. Pop: 83.8M. Cumulative incidence: 238/10⁵

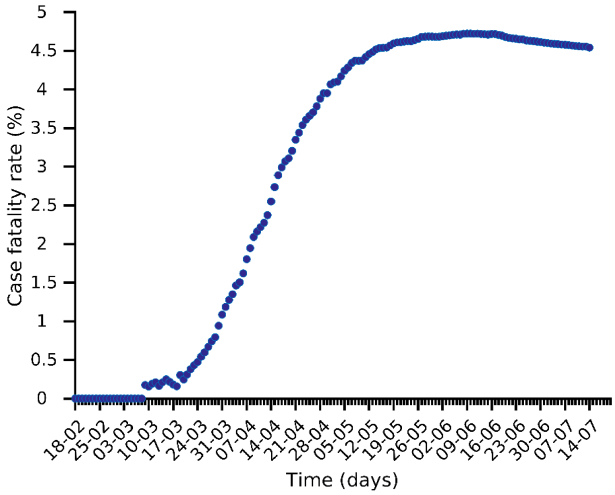


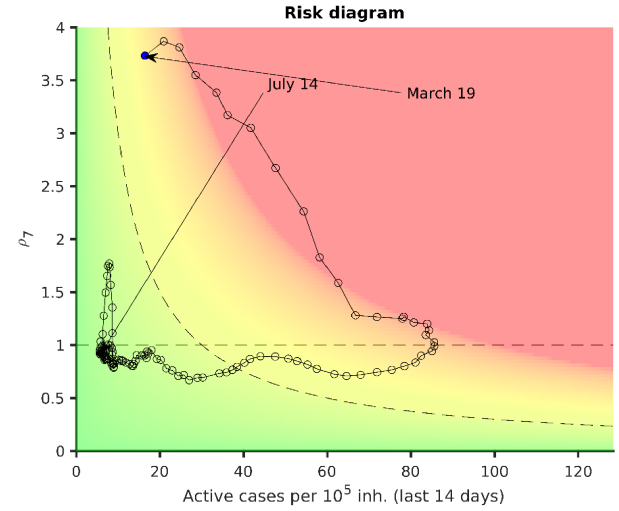


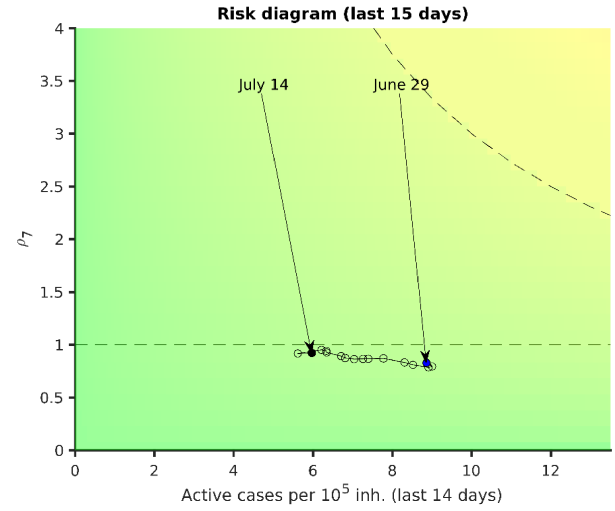




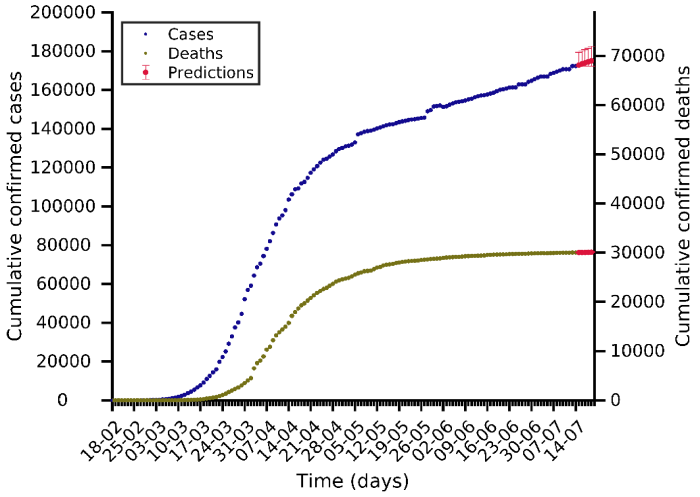


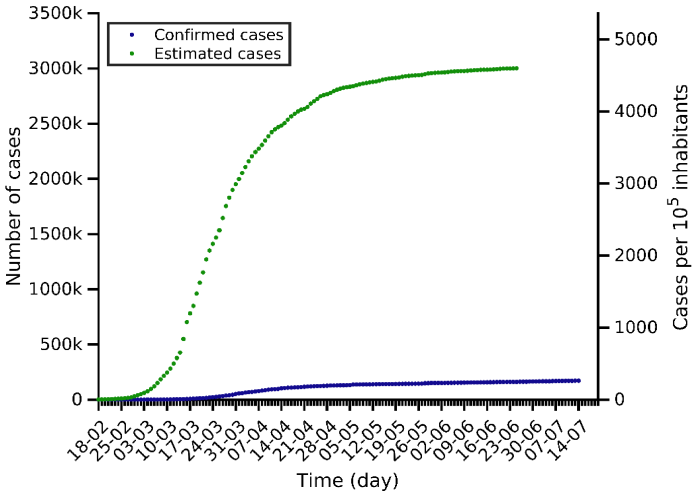


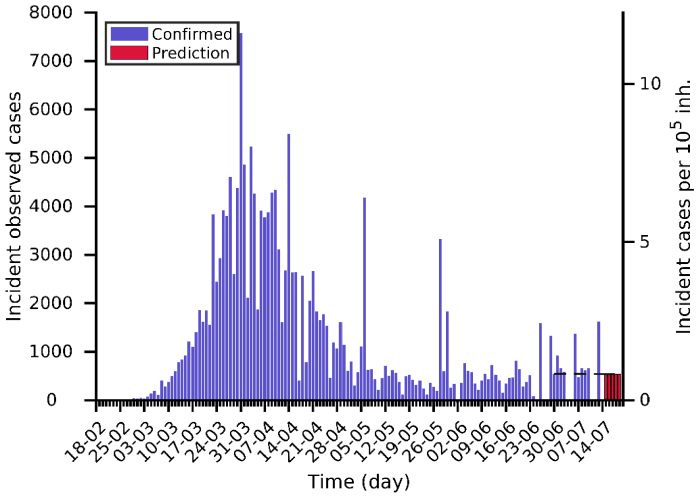


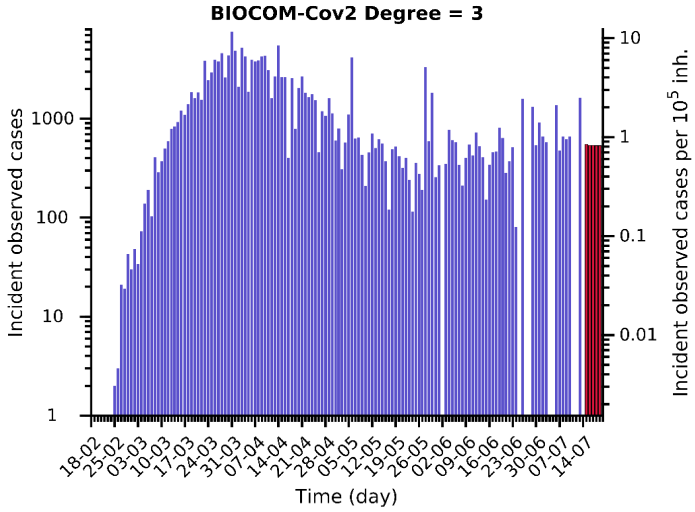


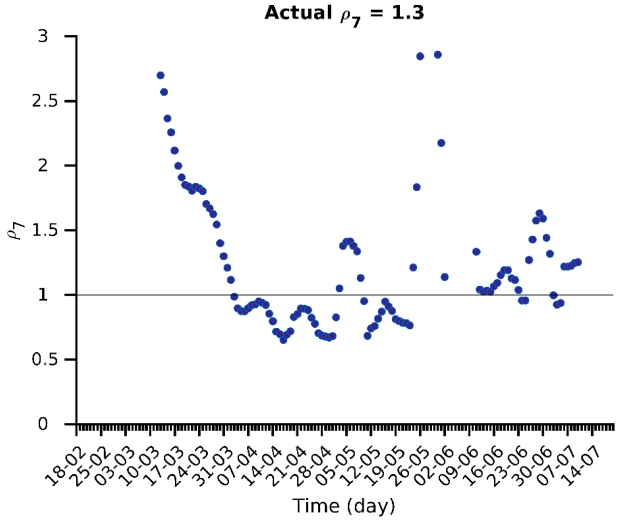
France 14-07-2020. Pop: 65.3M. Cumulative incidence: 264/10⁵

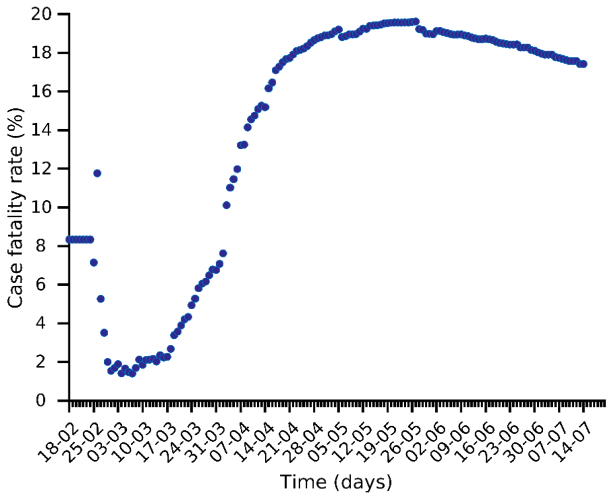


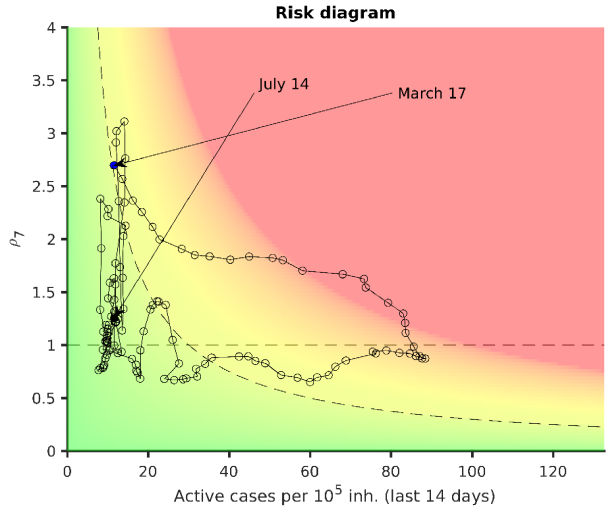


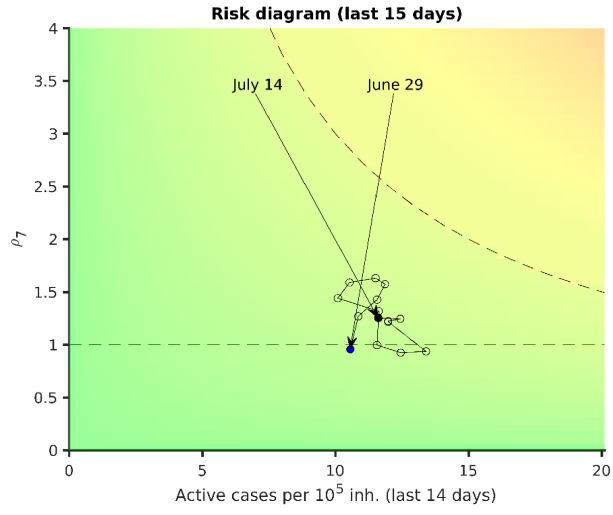




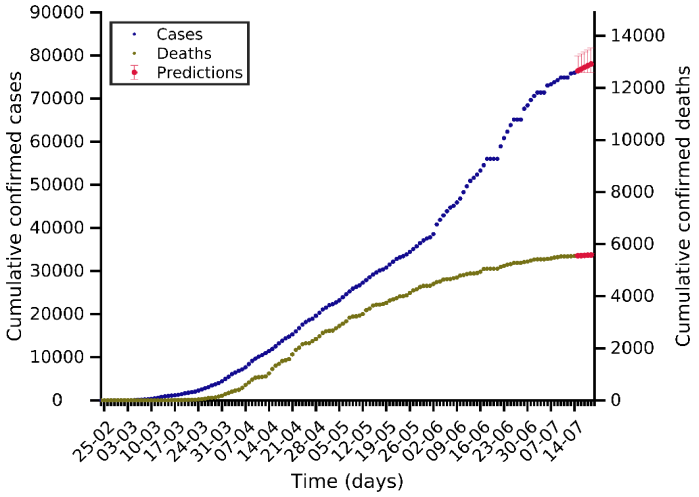


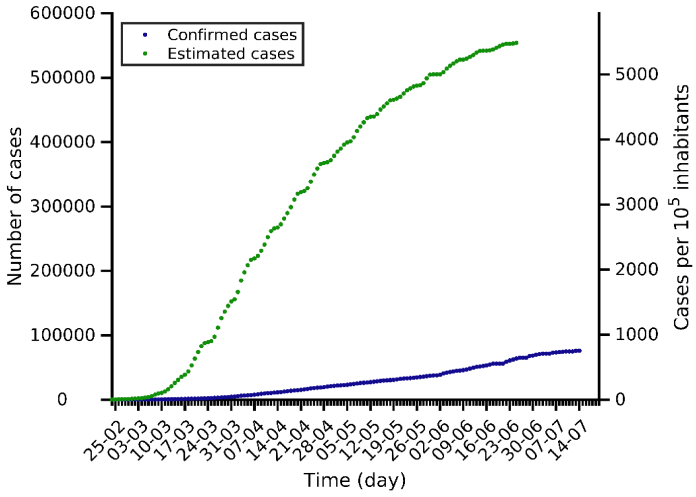


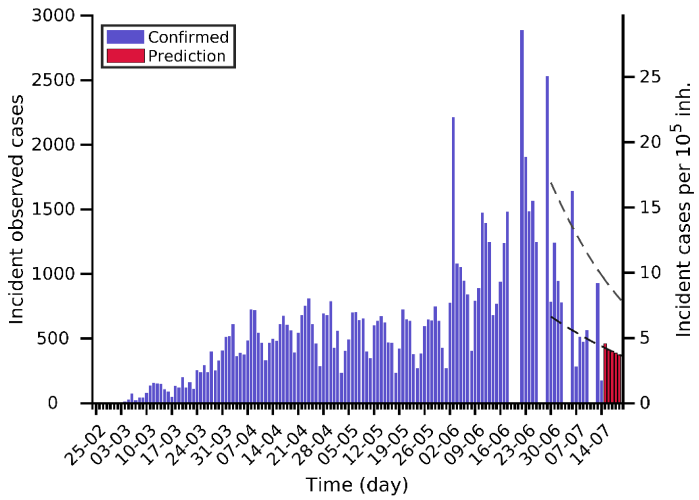


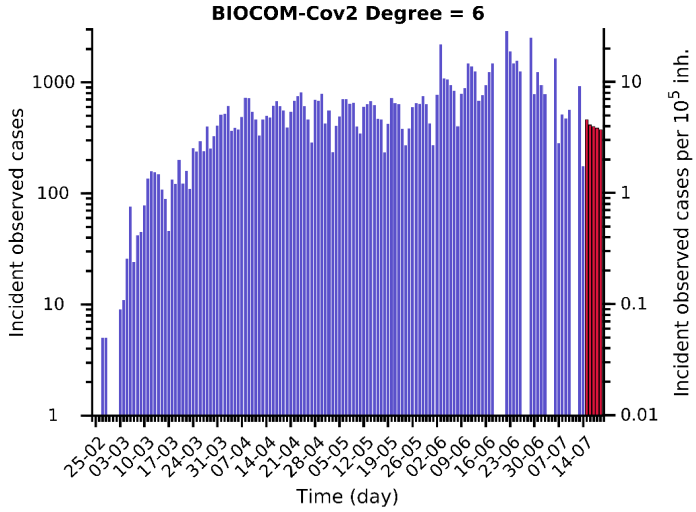


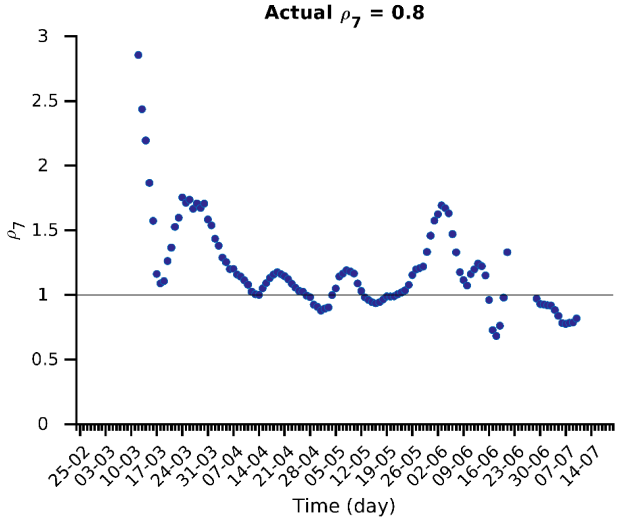
Sweden 14-07-2020. Pop: 10.1M. Cumulative incidence: 753/10⁵

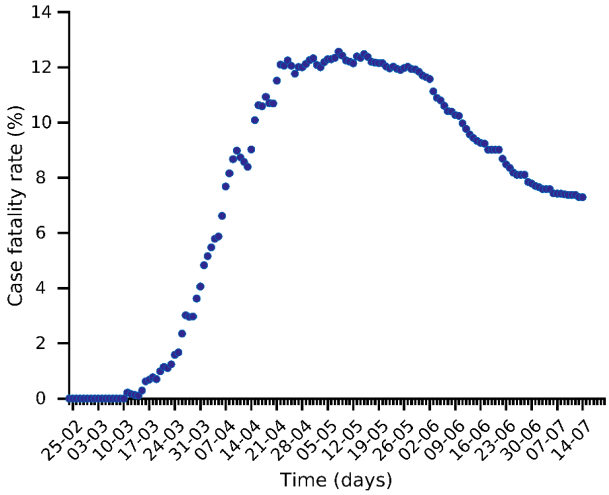


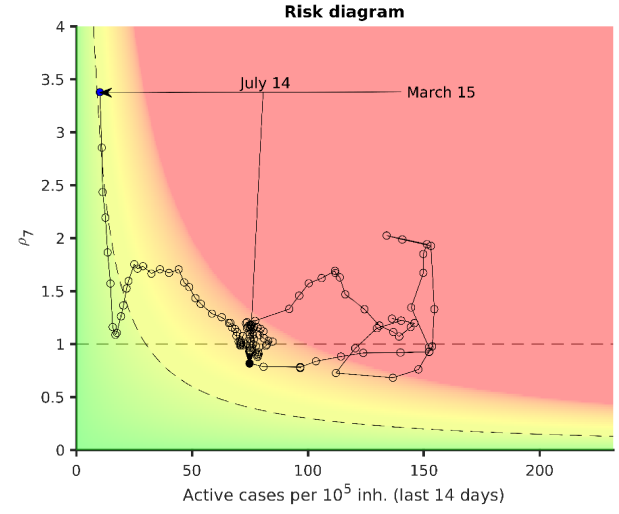


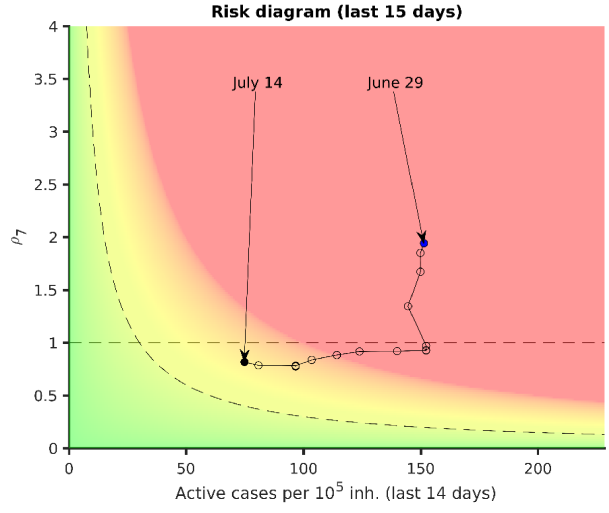




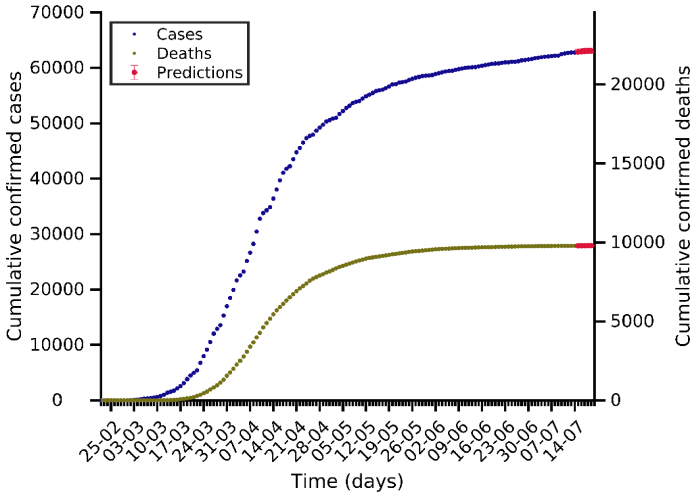


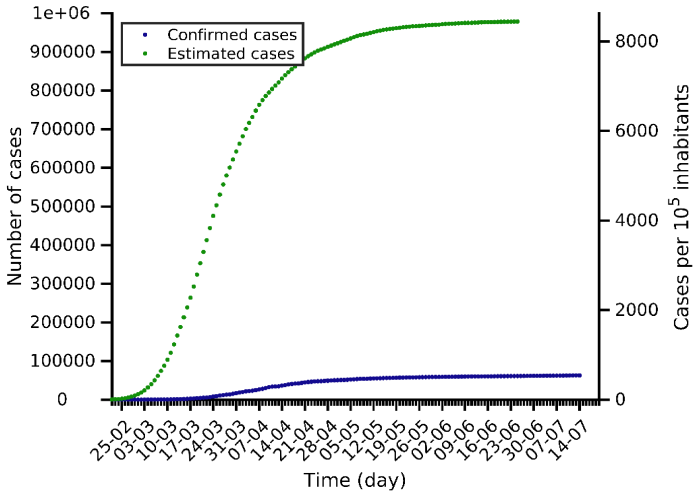


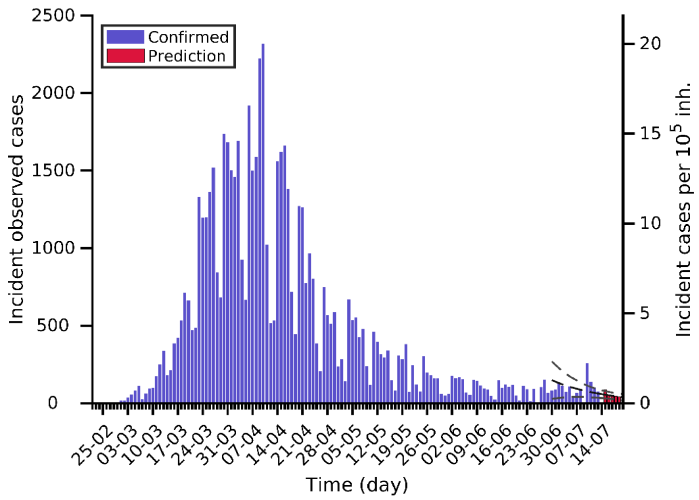


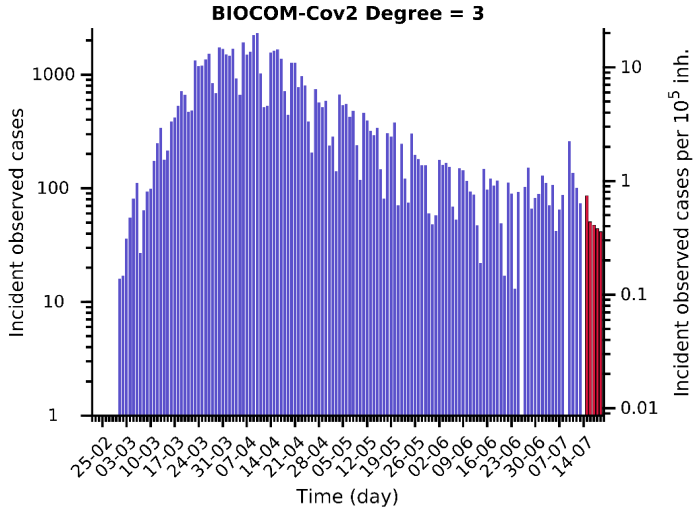


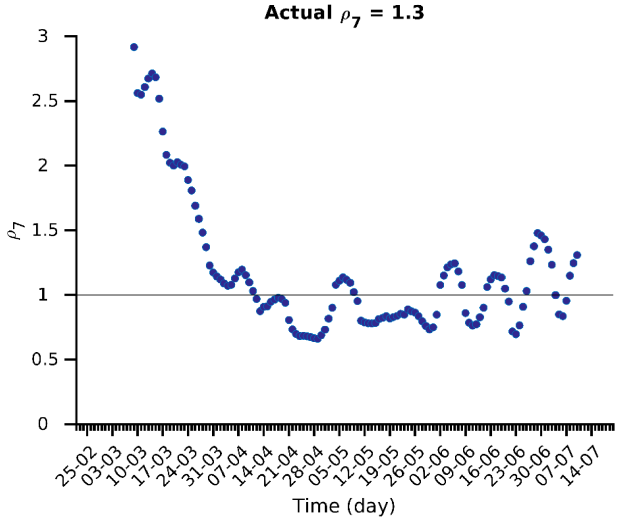
Belgium 14-07-2020. Pop: 11.6M. Cumulative incidence: 542/10^5

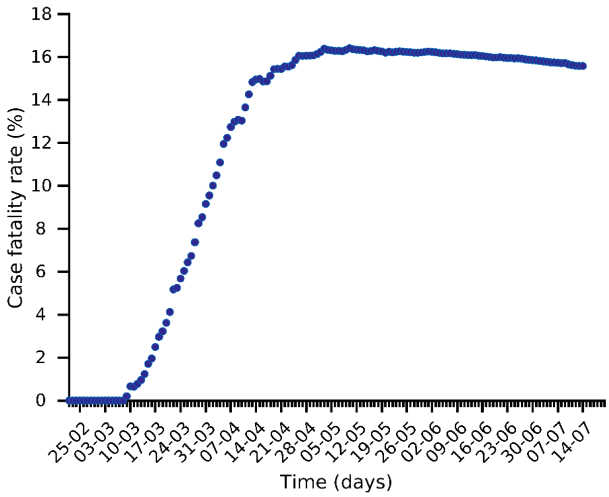


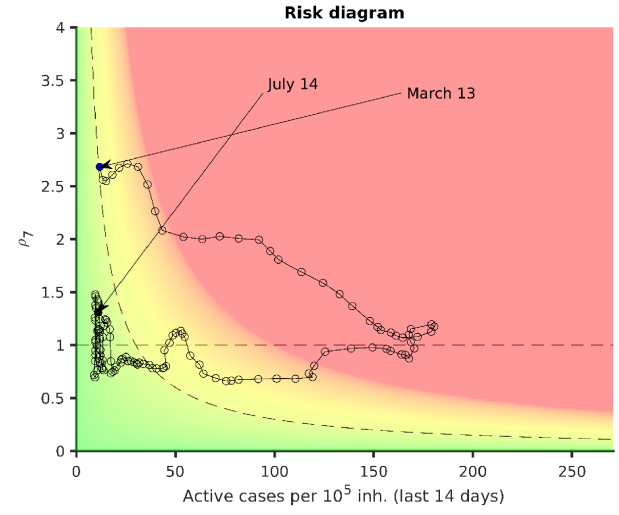


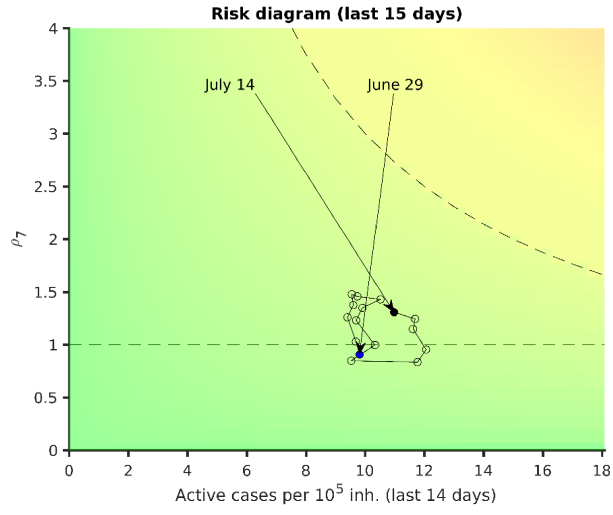




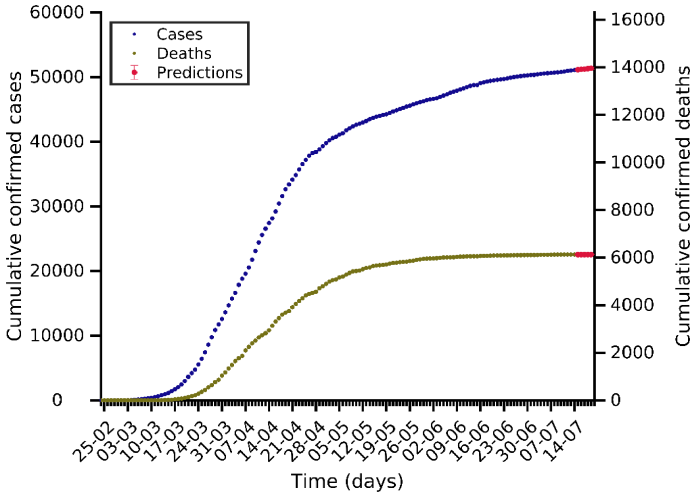


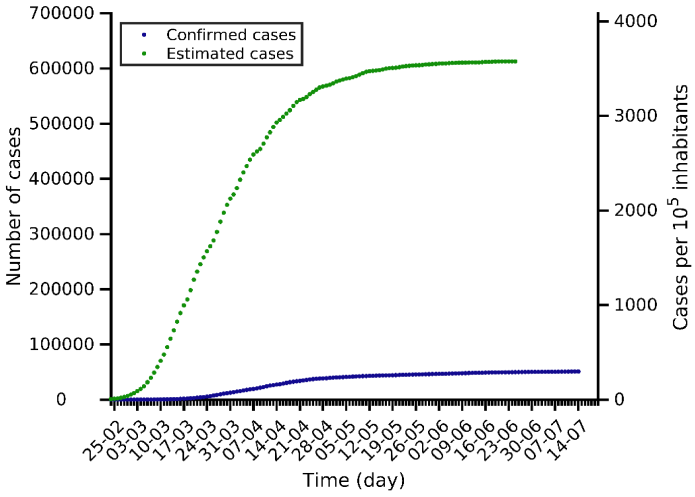


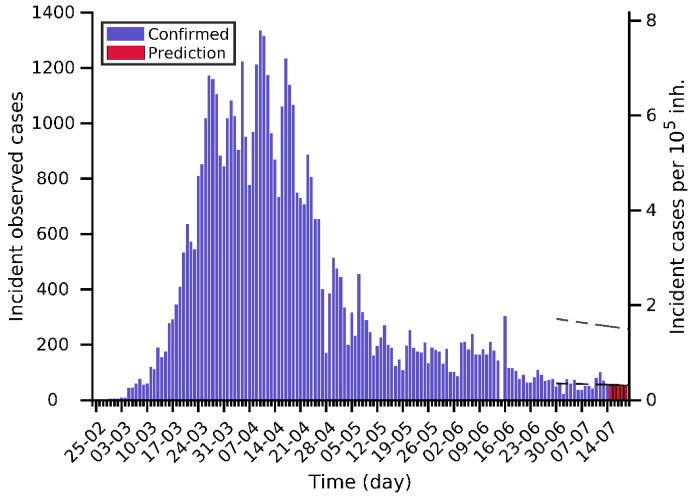


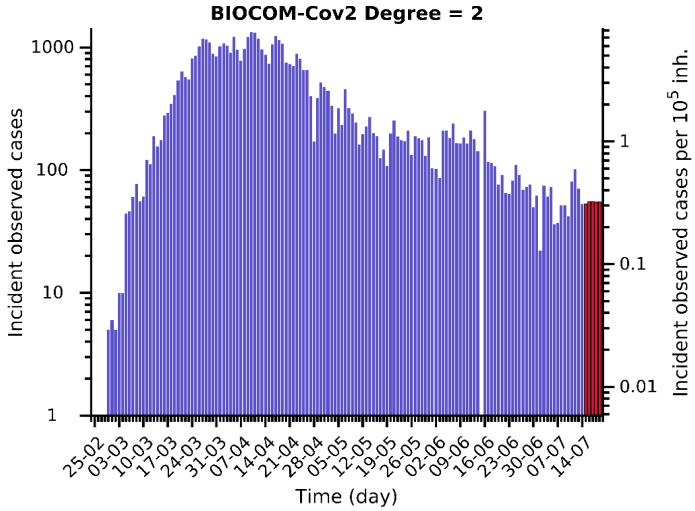


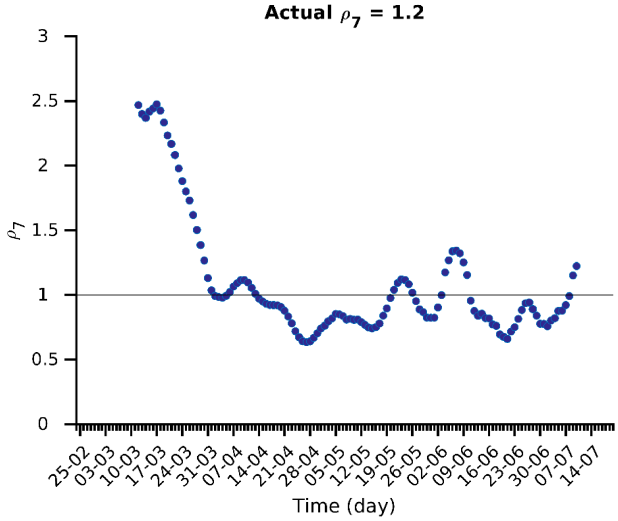
Netherlands 14-07-2020. Pop: 17.1M. Cumulative incidence: 298/10⁵

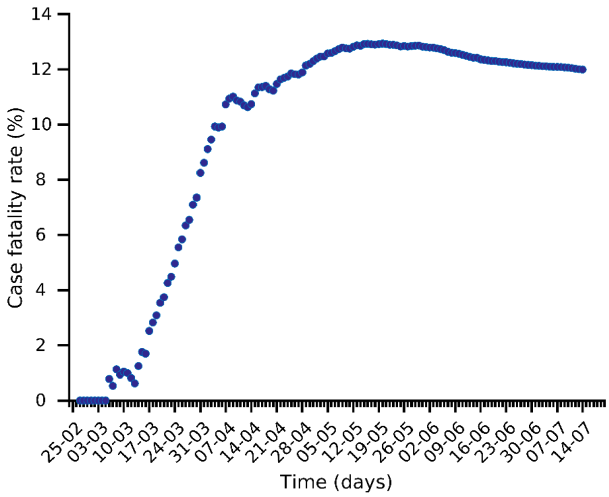


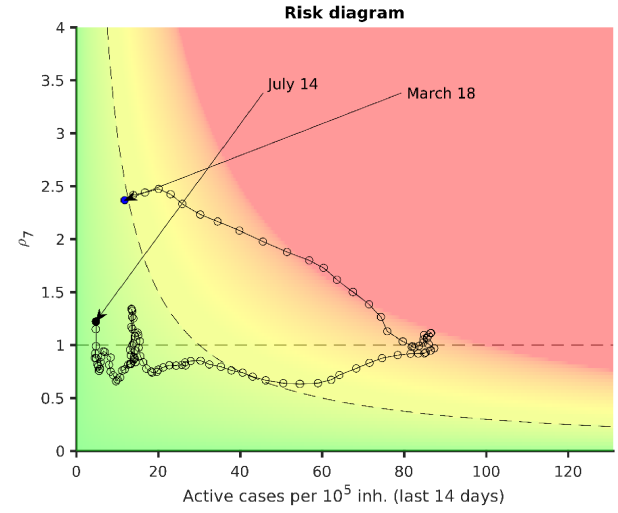


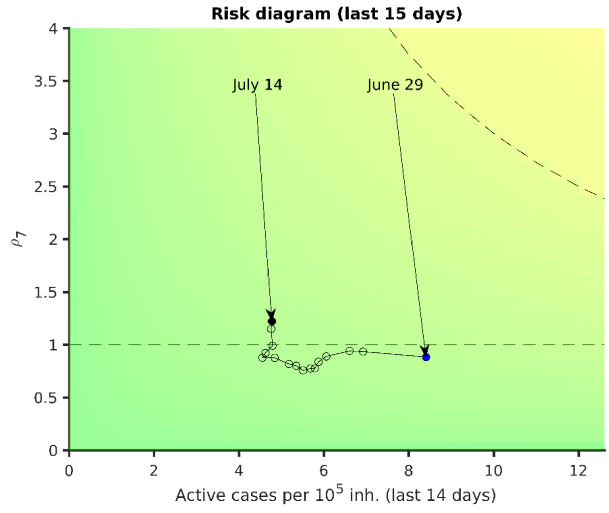




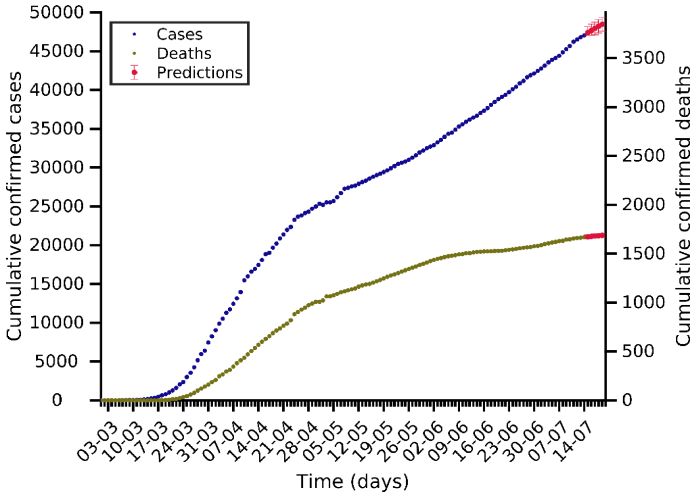


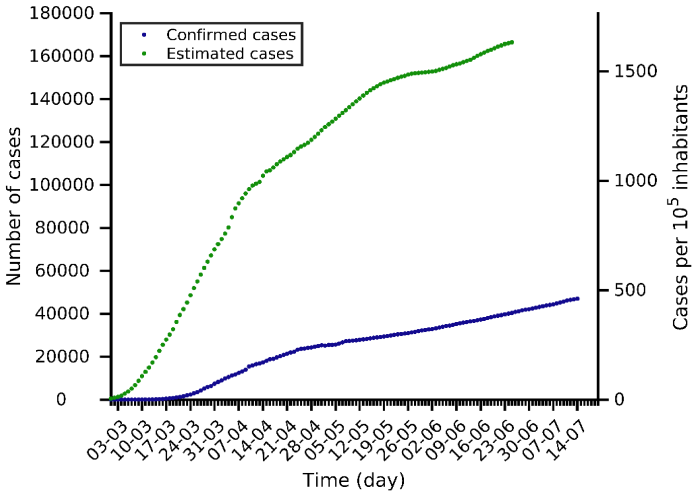


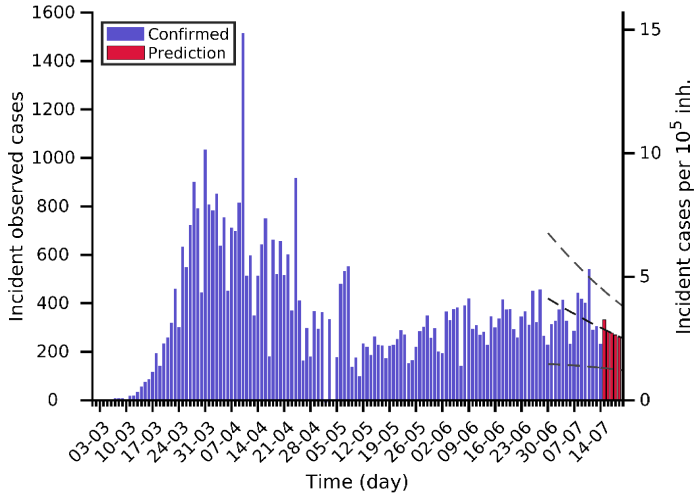


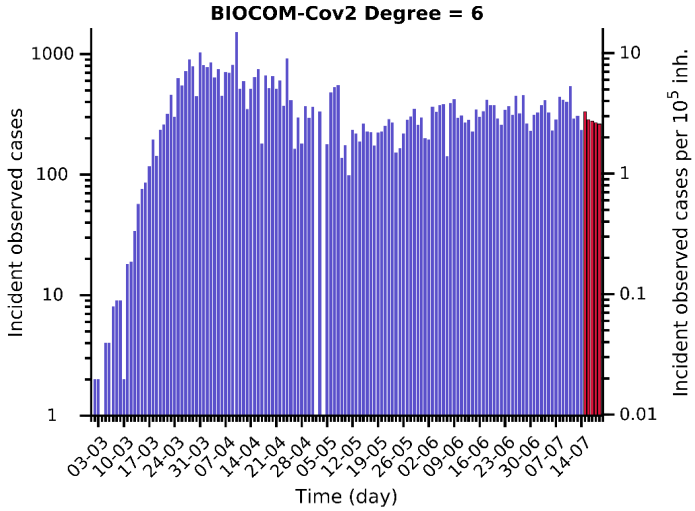


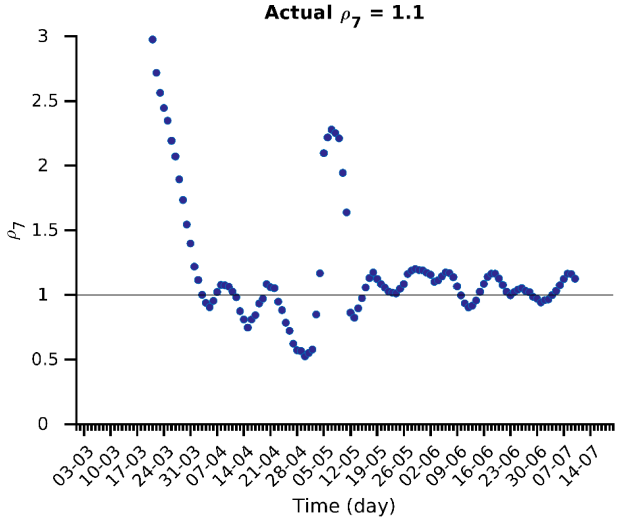
Portugal 14-07-2020. Pop: 10.2M. Cumulative incidence: 461/10⁵

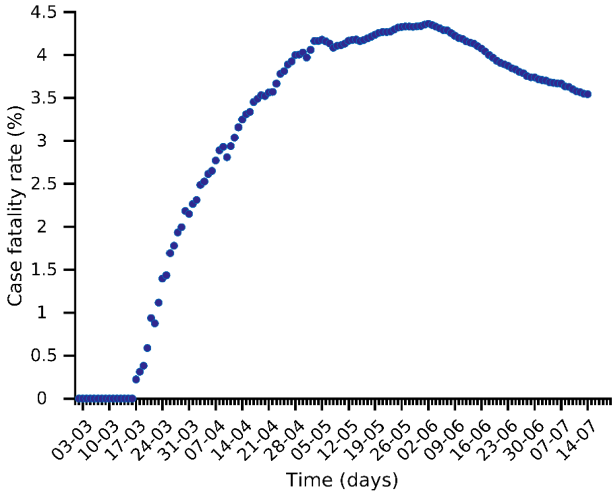


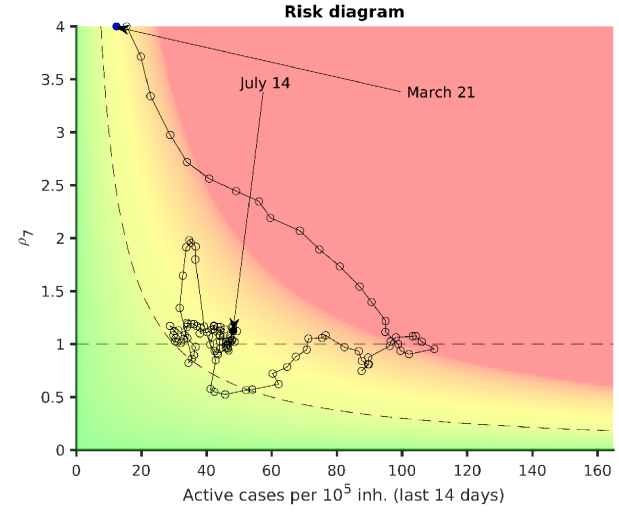


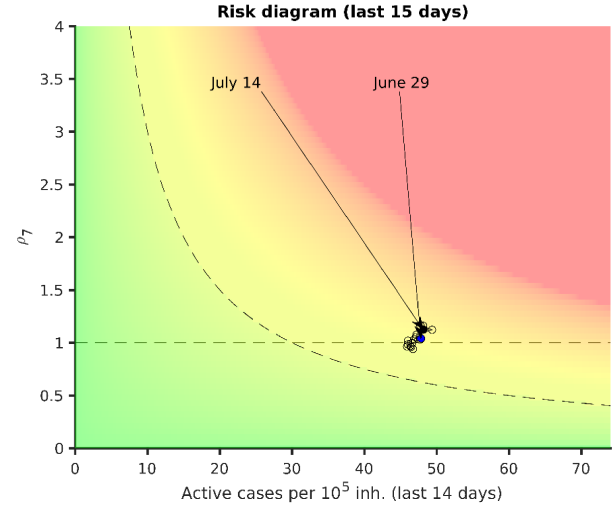




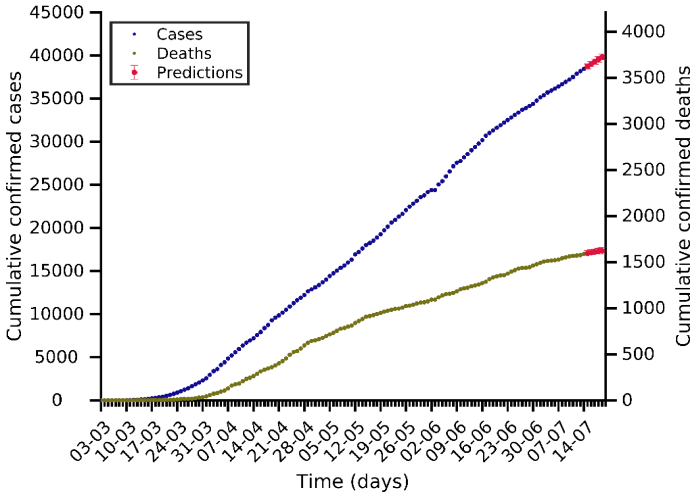


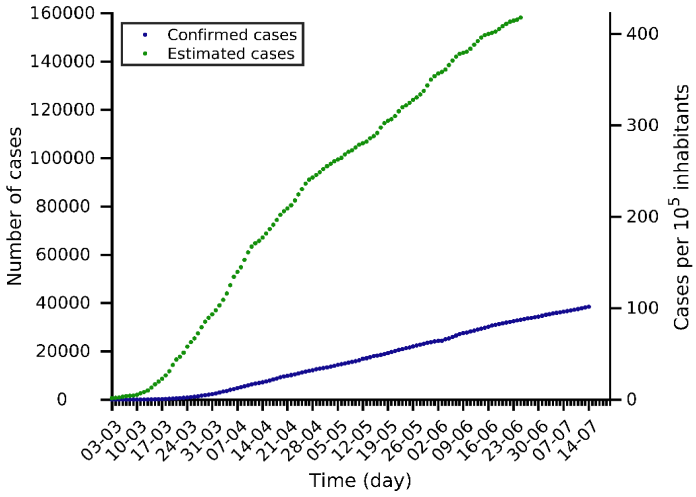


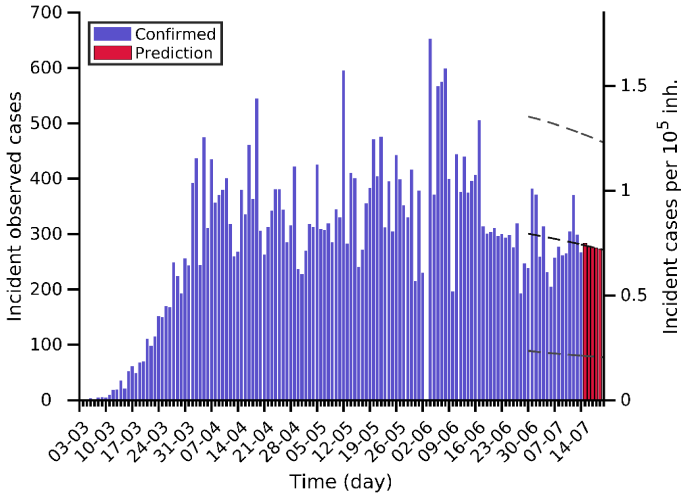


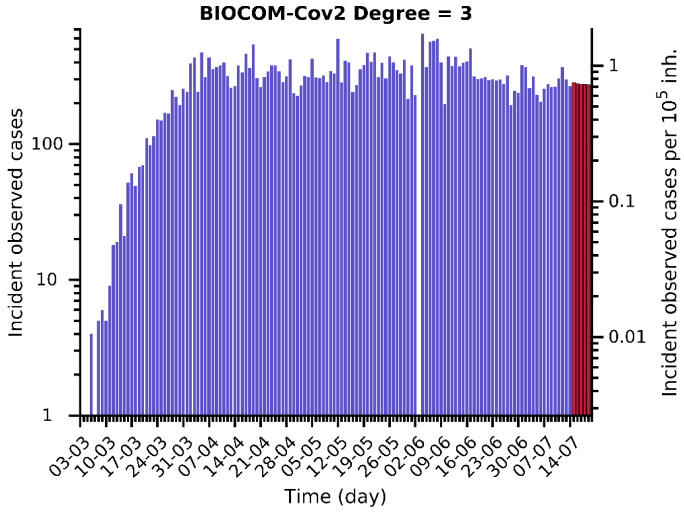


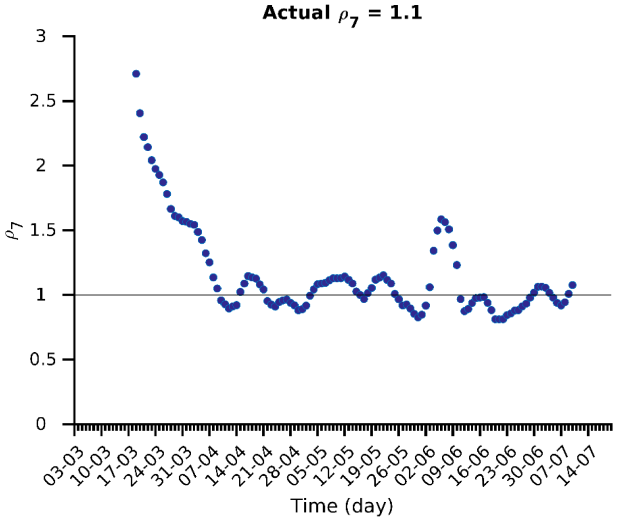
Poland 14-07-2020. Pop: 37.8M. Cumulative incidence: 102/10⁵

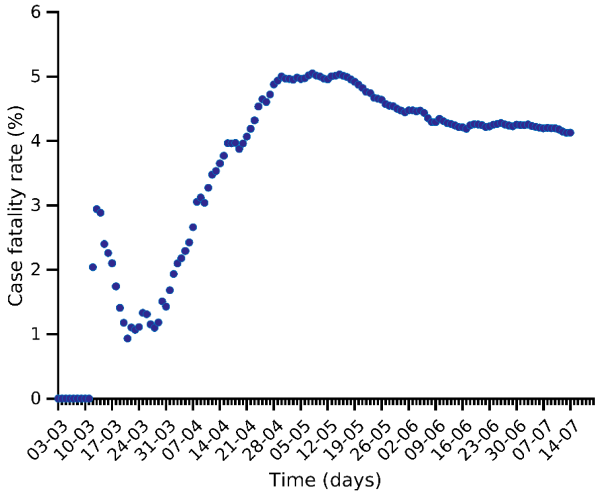


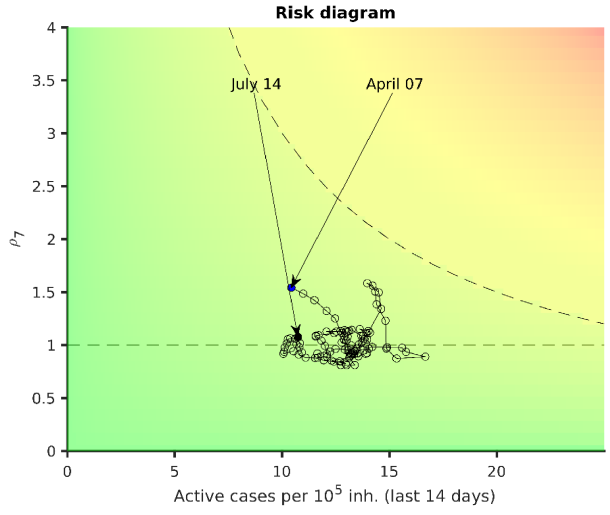


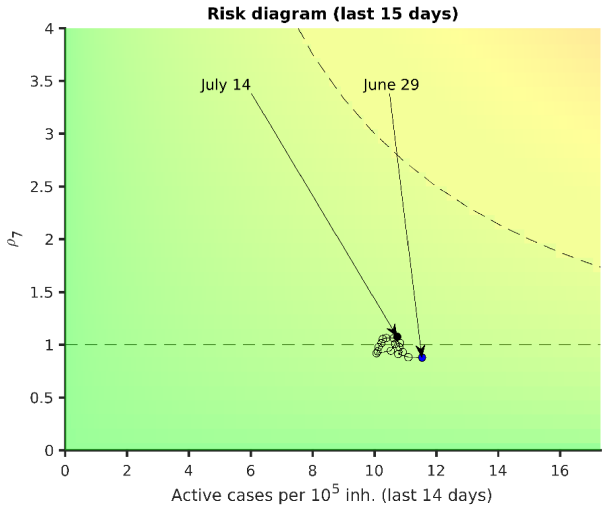




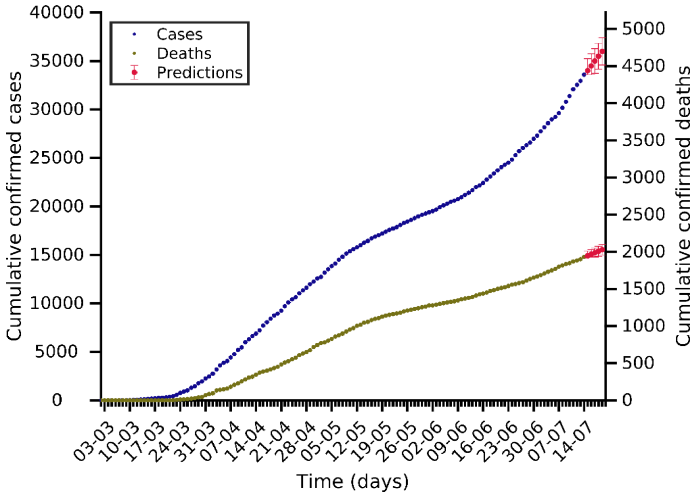


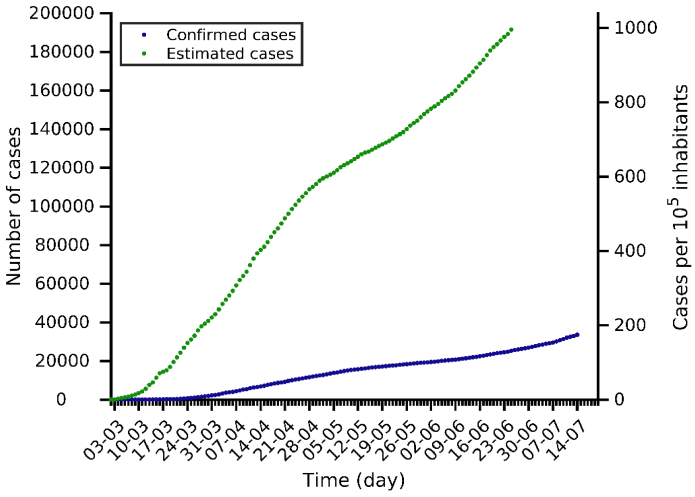


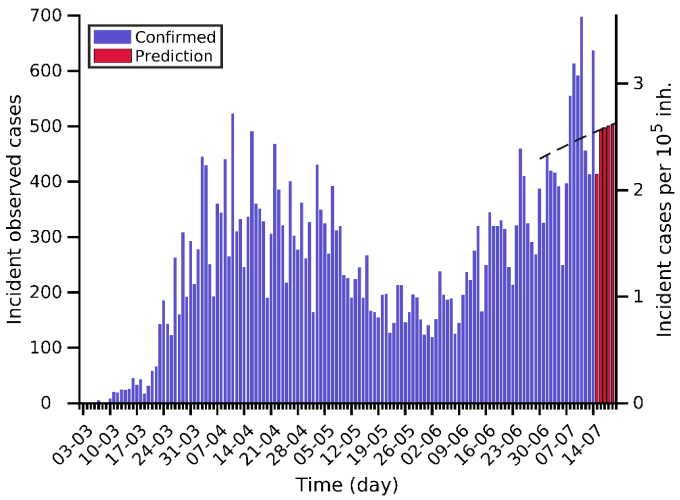


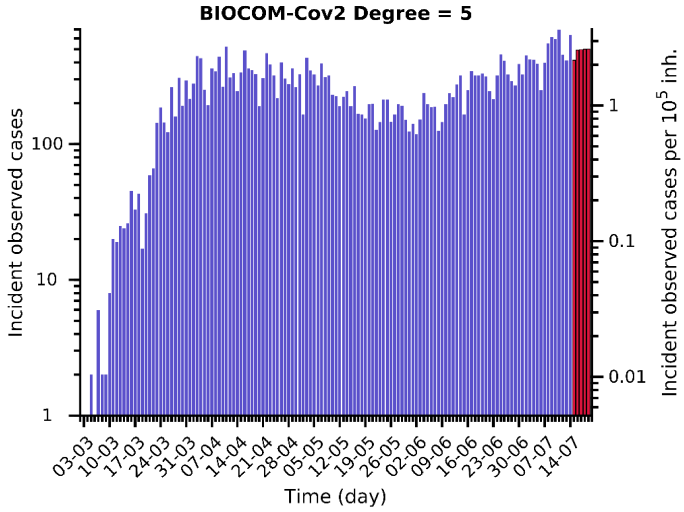


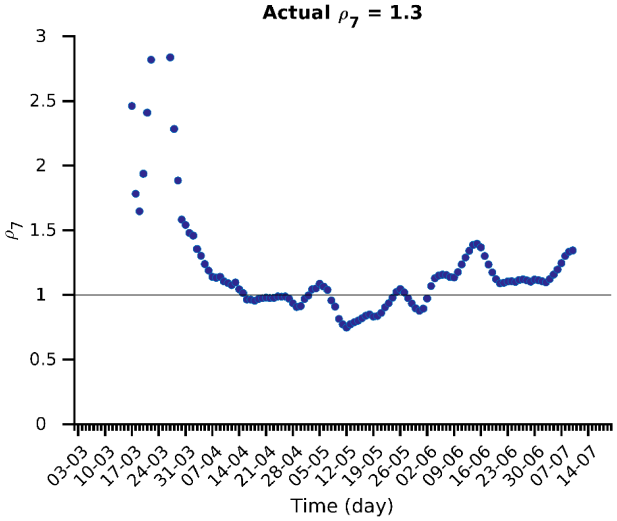
Romania 14-07-2020. Pop: 19.2M. Cumulative incidence: 175/10^5

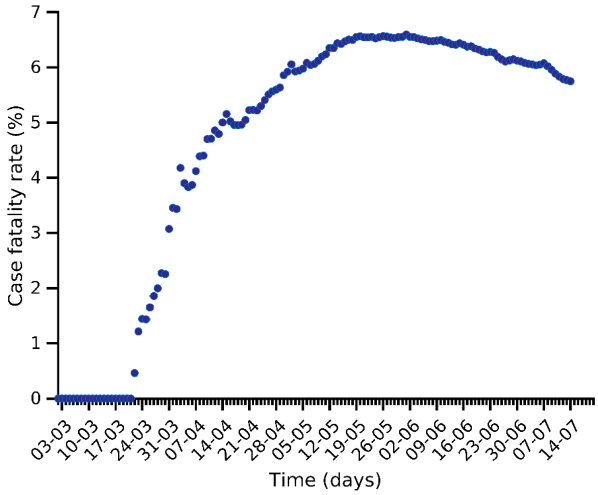


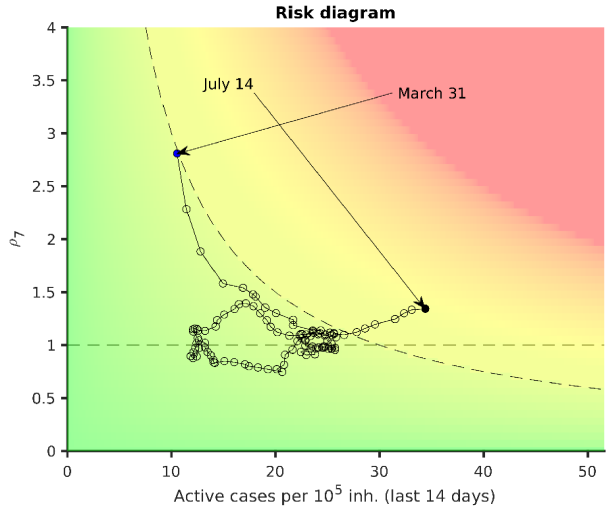


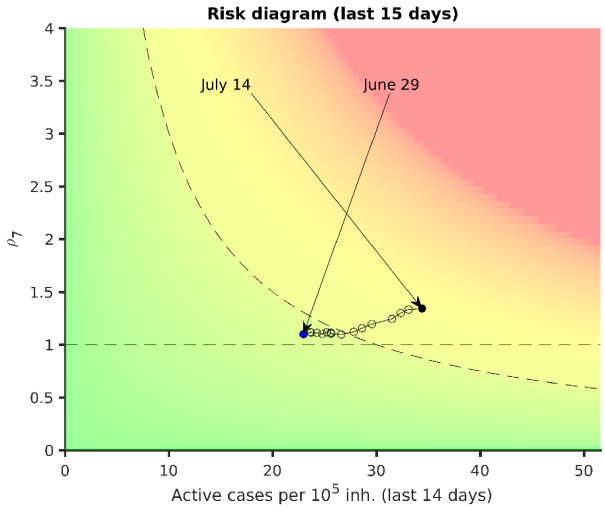




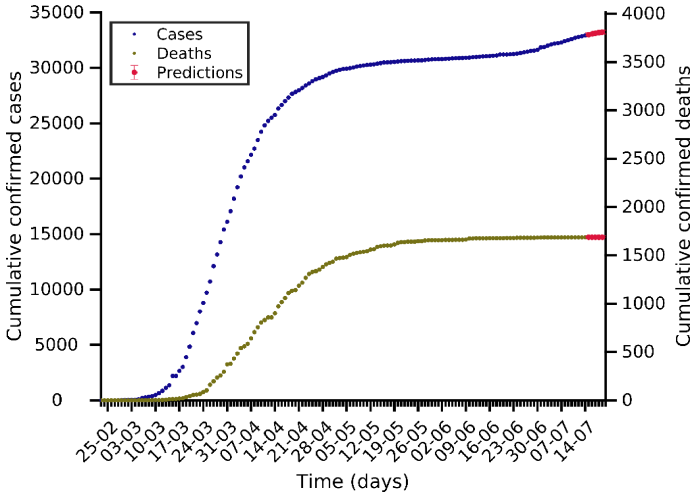


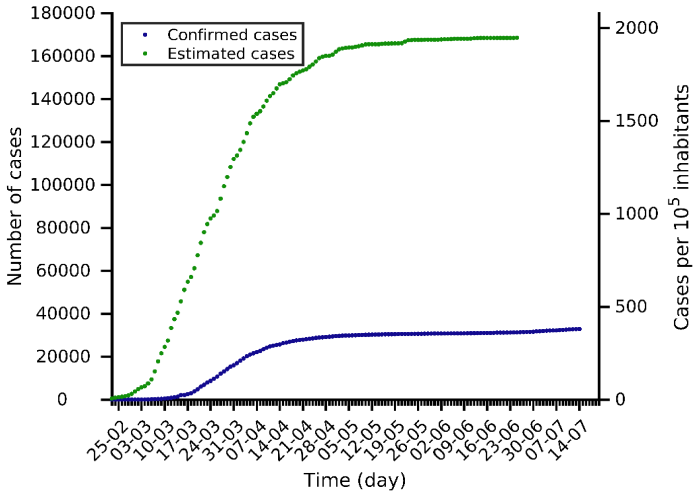


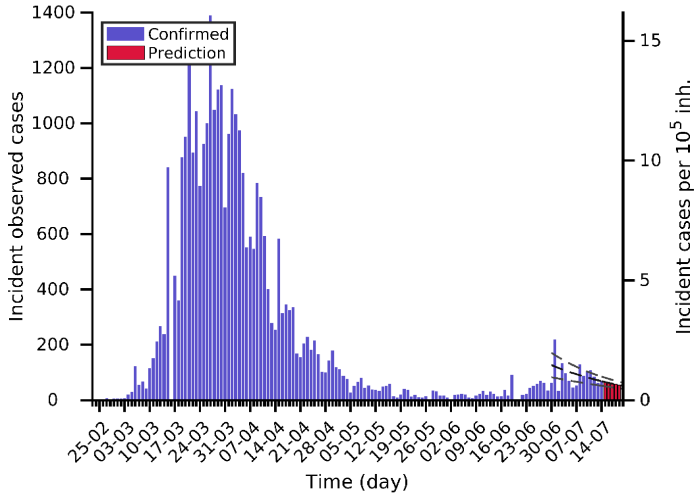


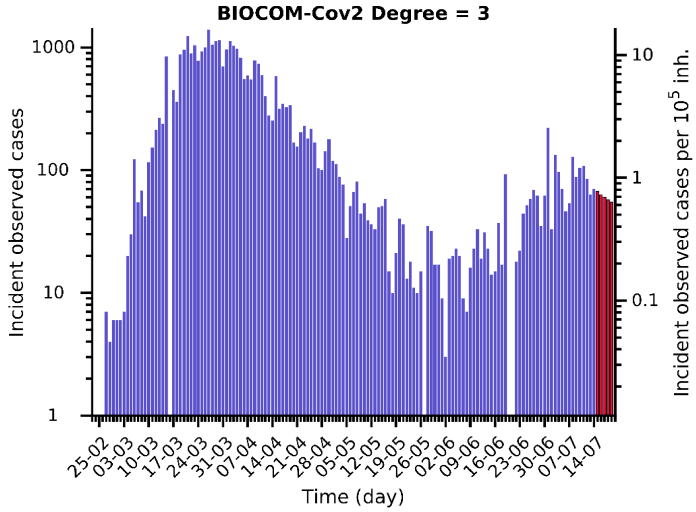


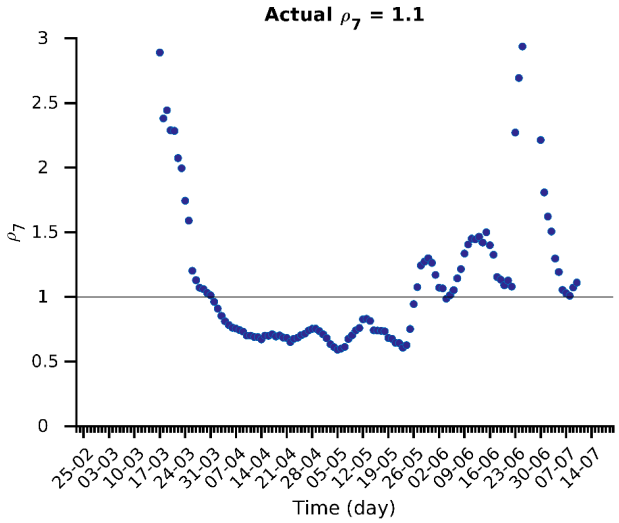
Switzerland 14-07-2020. Pop: 8.7M. Cumulative incidence: 381/10⁵

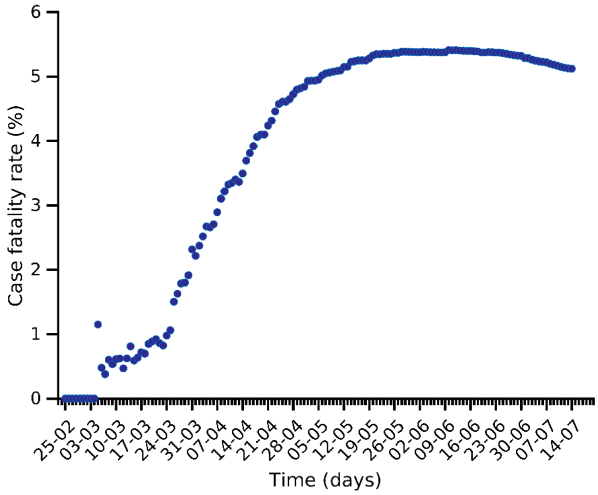


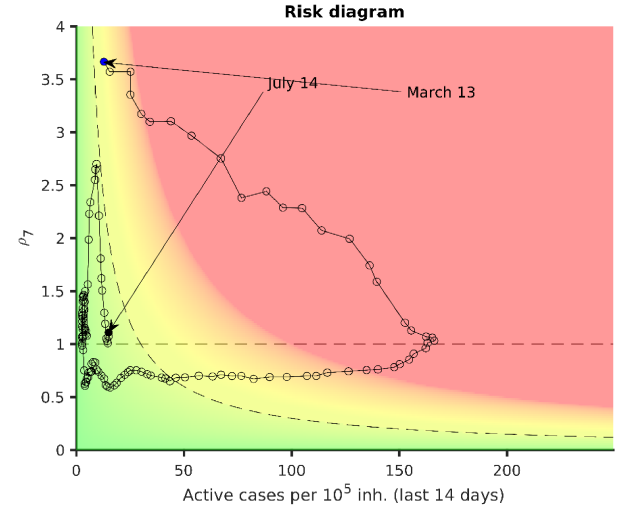


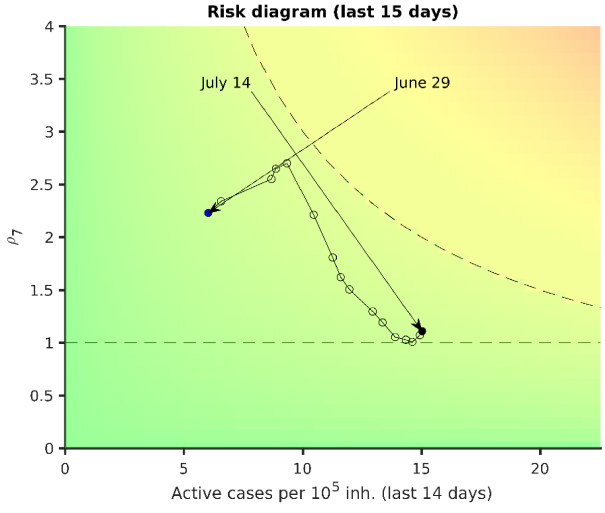




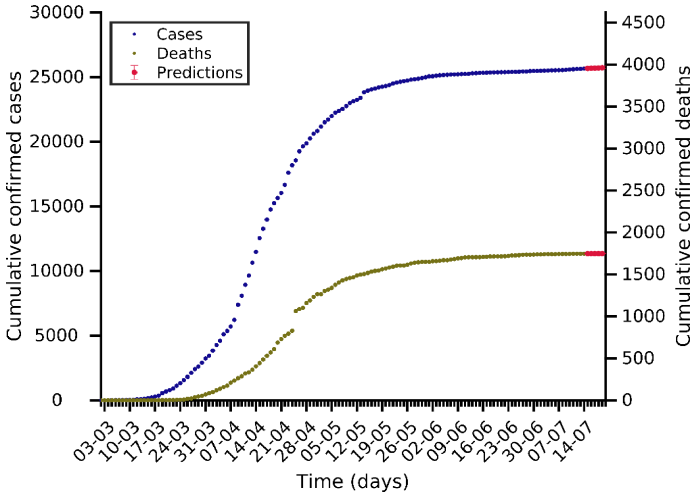


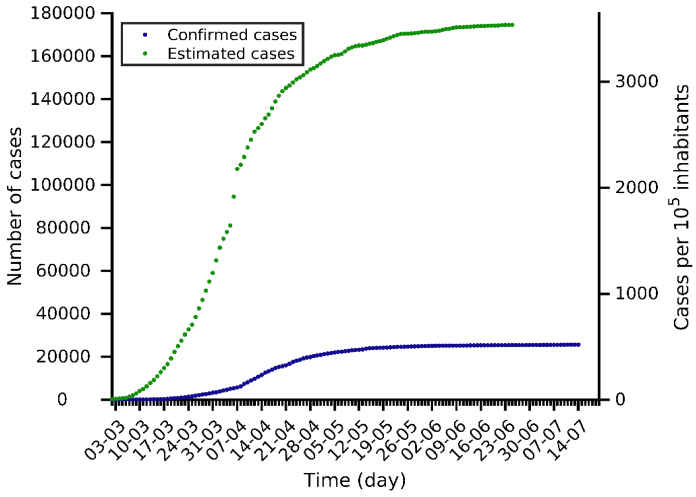


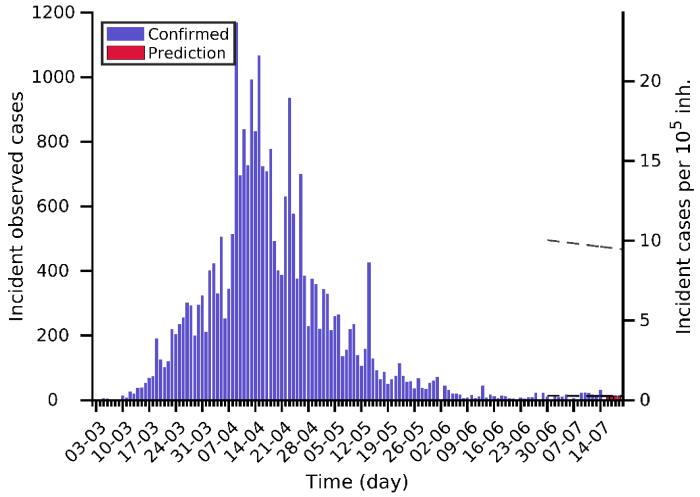


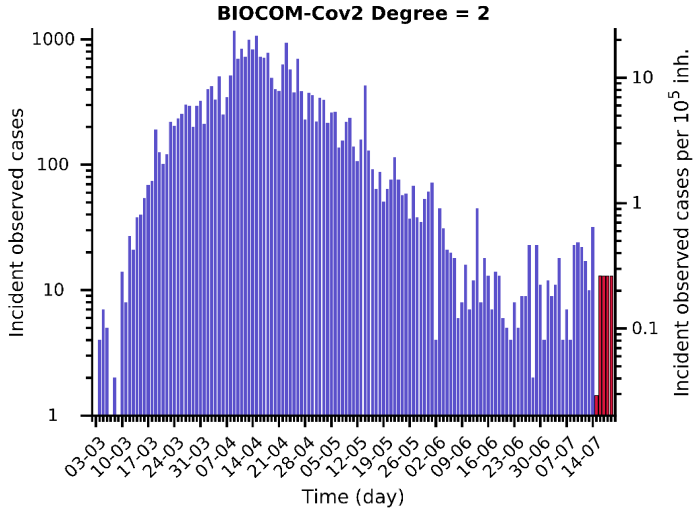


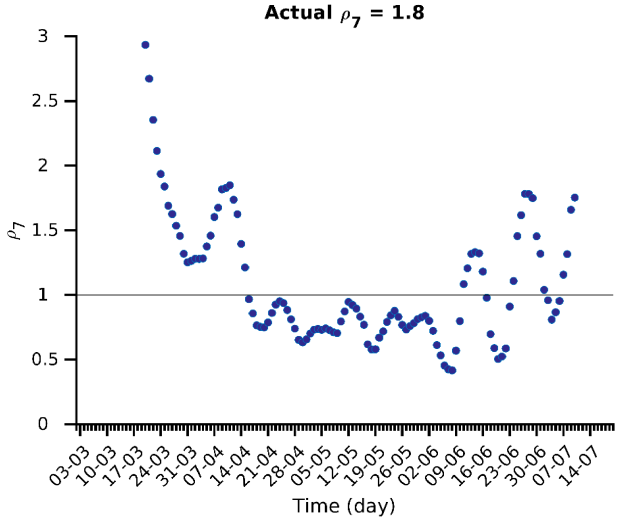
Ireland 14-07-2020. Pop: 4.9M. Cumulative incidence: 520/10⁵

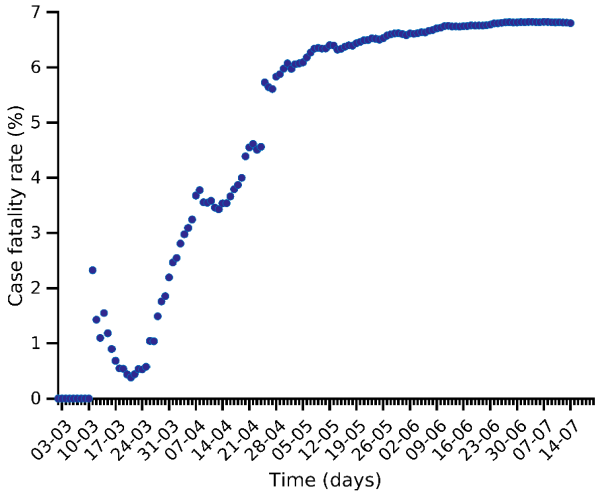


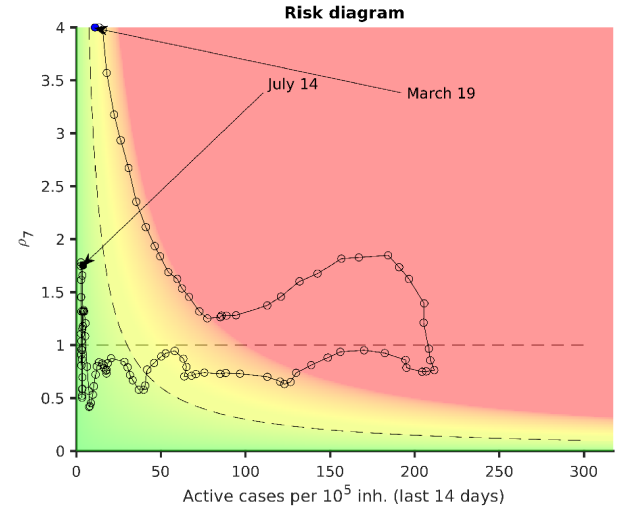


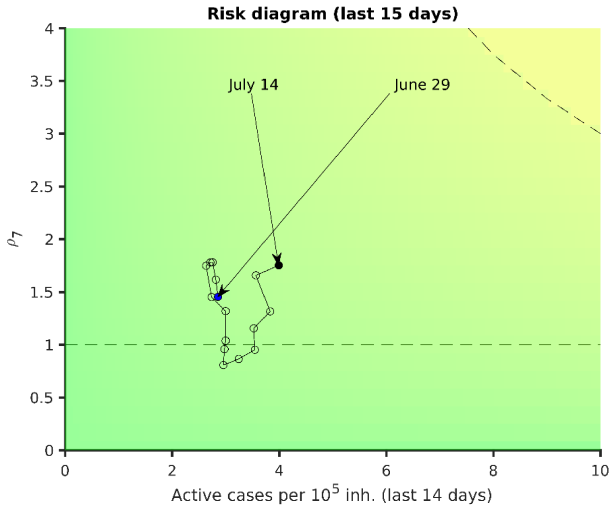




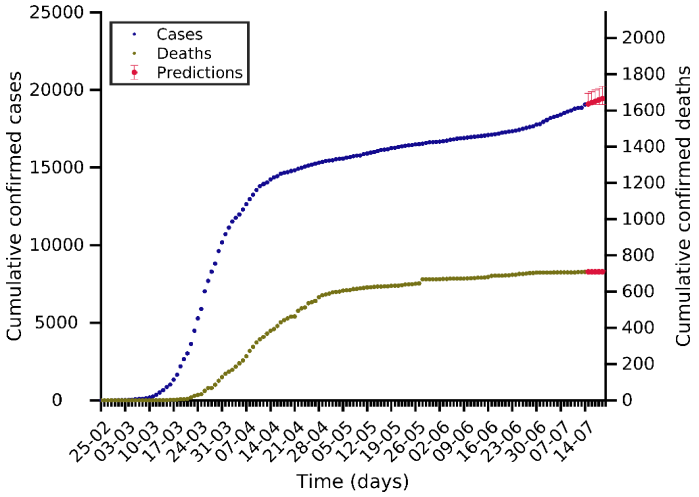


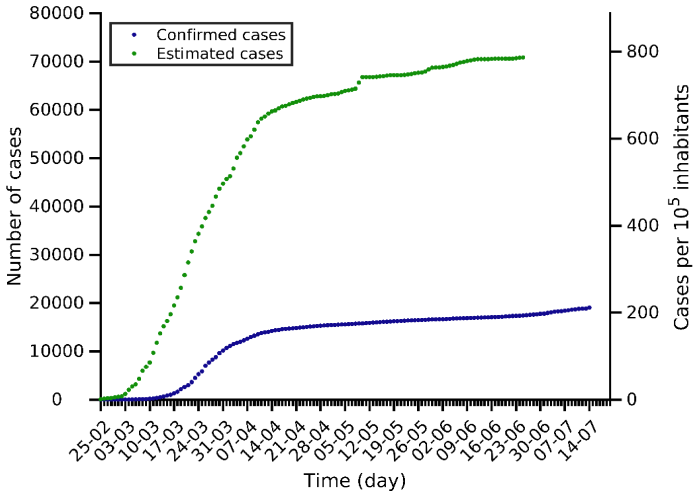


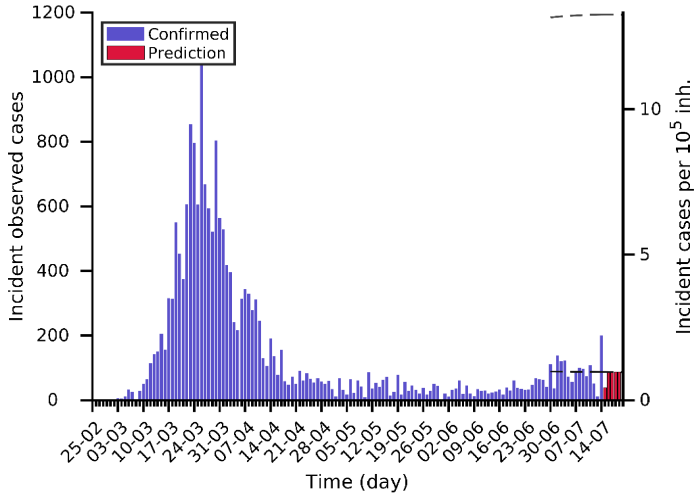


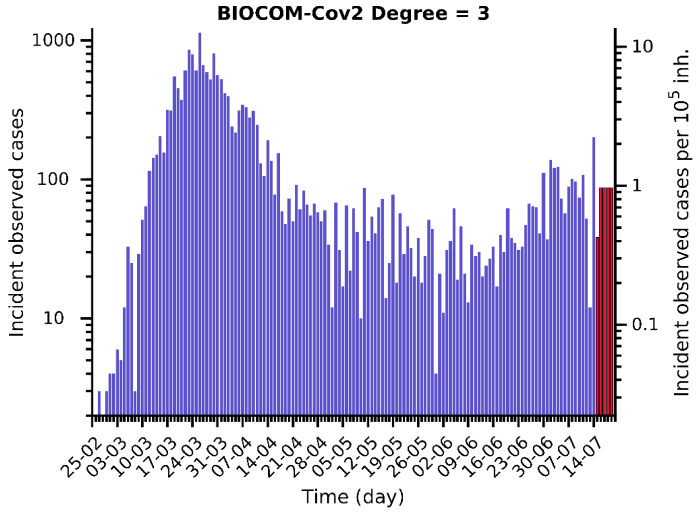


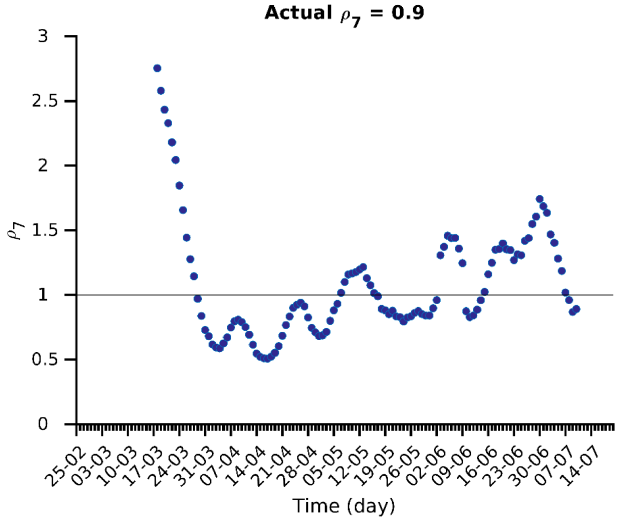
Austria 14-07-2020. Pop: 9.0M. Cumulative incidence: 212/10⁵

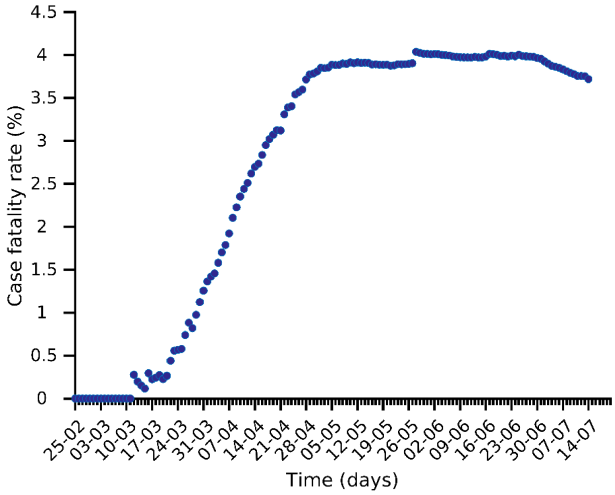


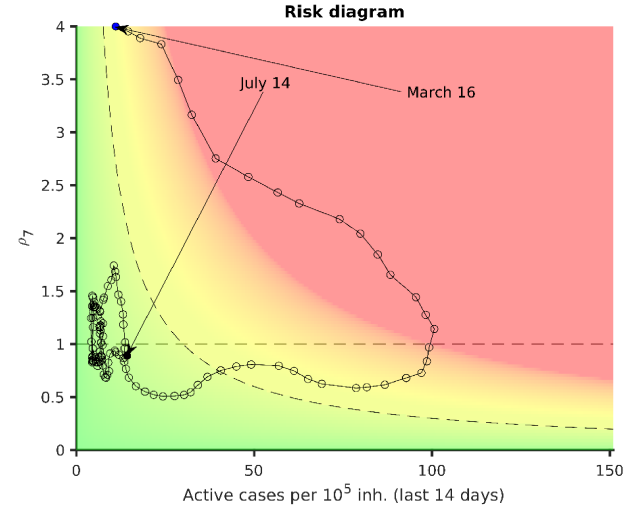


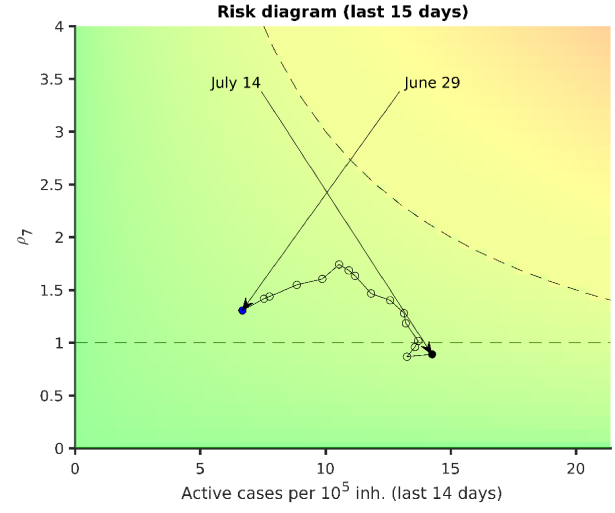




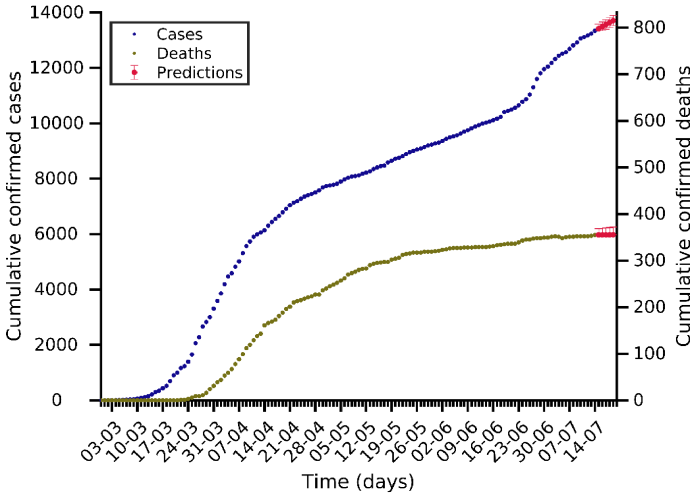


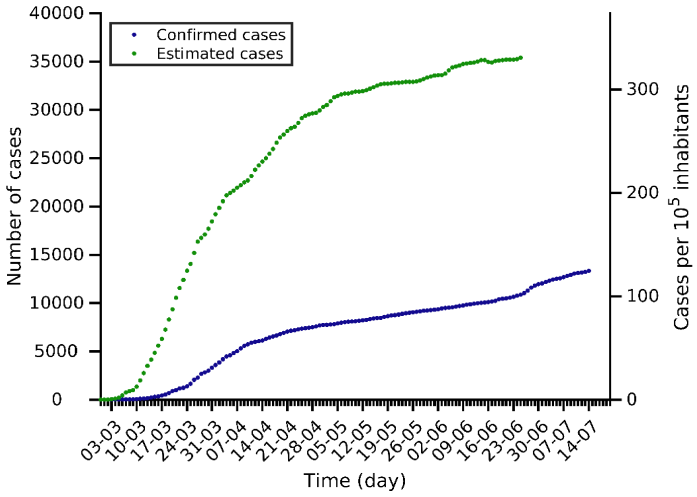


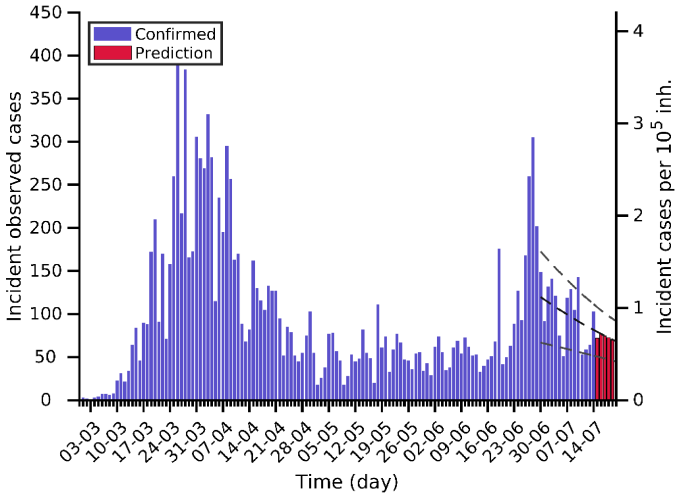


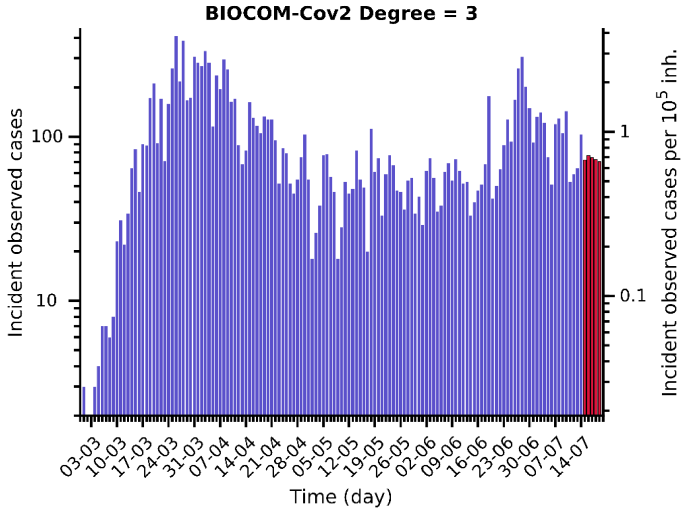


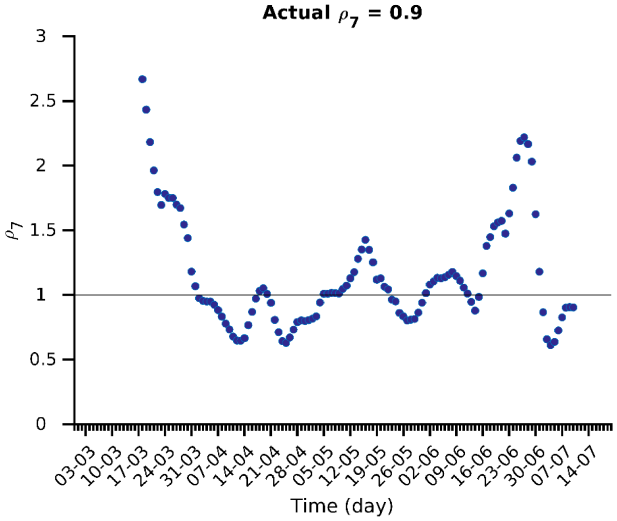
Czech Rep 14-07-2020. Pop: 10.7M. Cumulative incidence: 125/10⁵

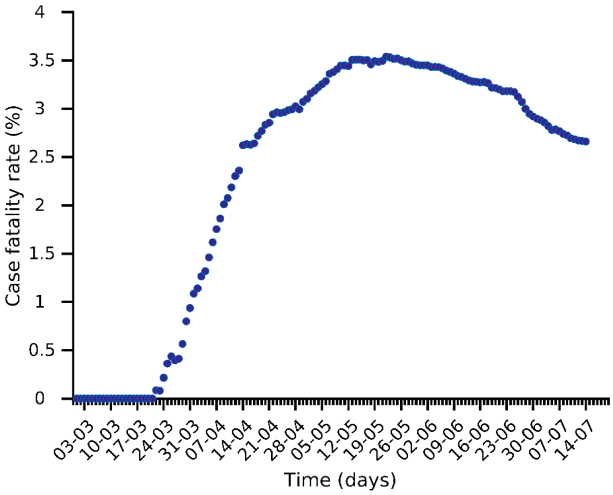


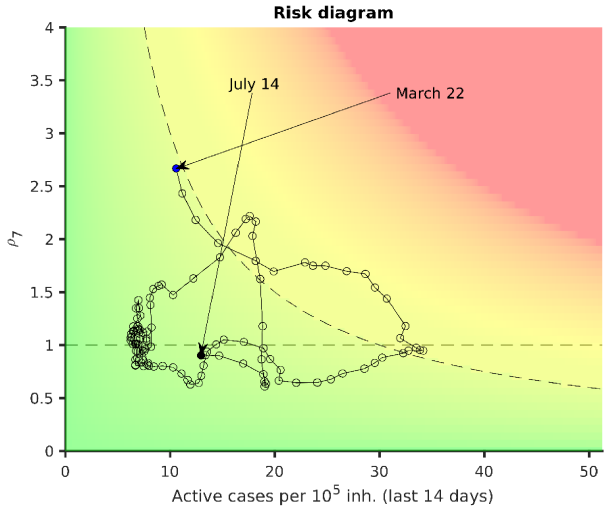


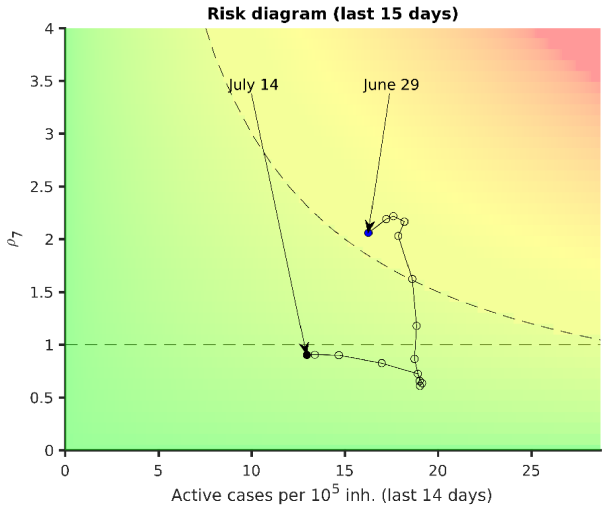




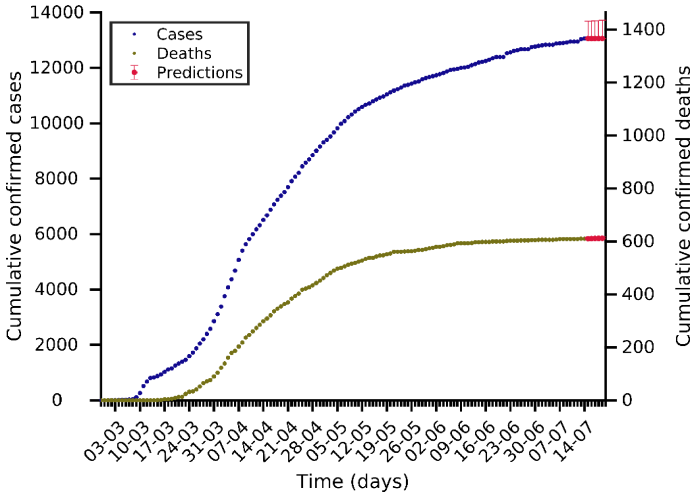


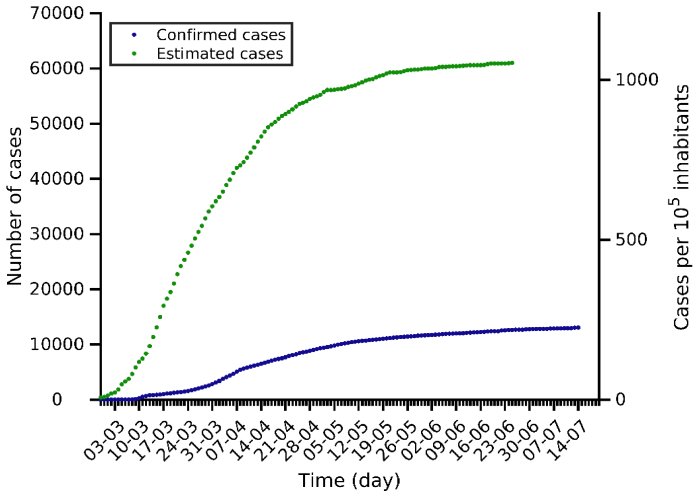


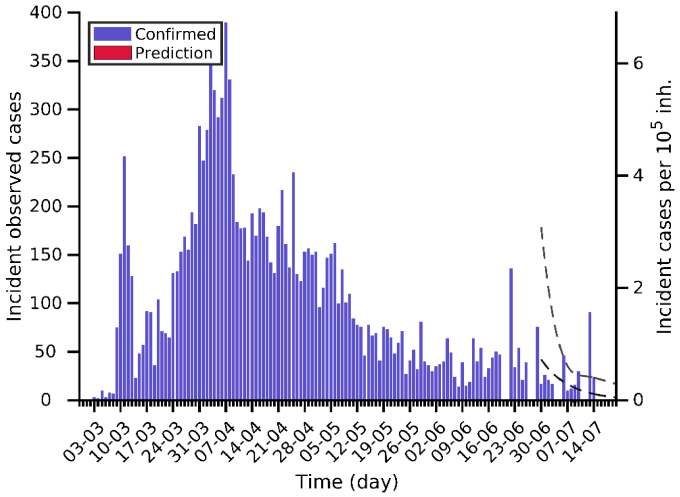


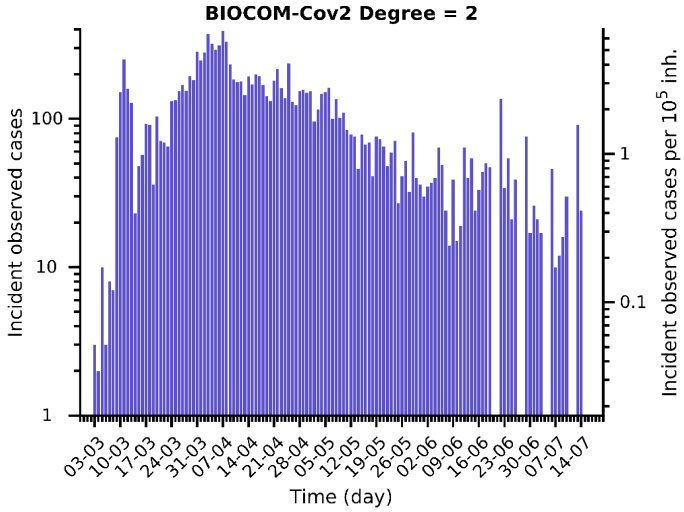


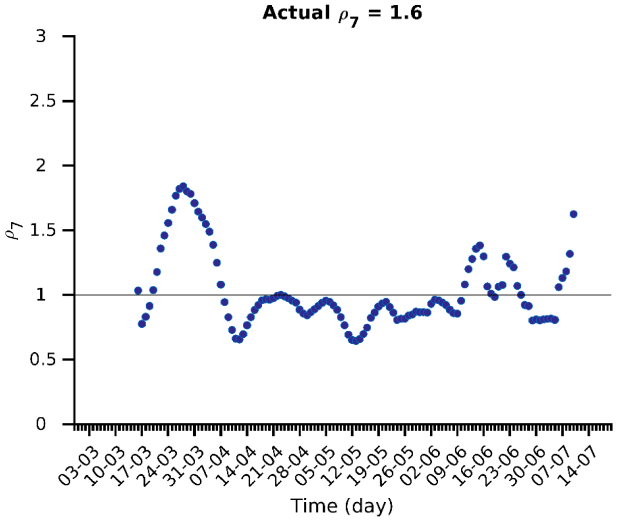
Denmark 14-07-2020. Pop: 5.8M. Cumulative incidence: 225/10⁵

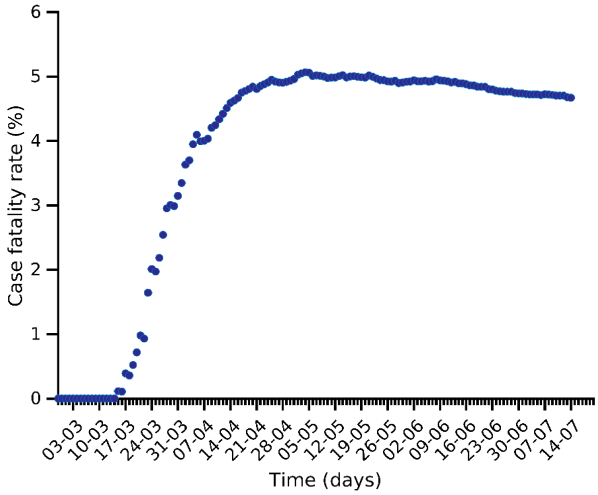


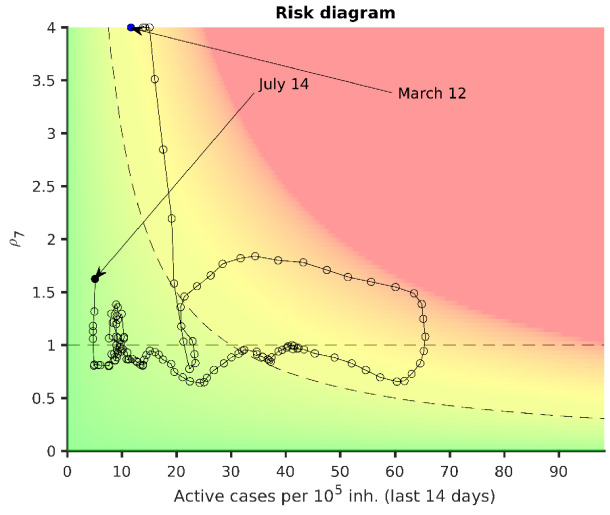


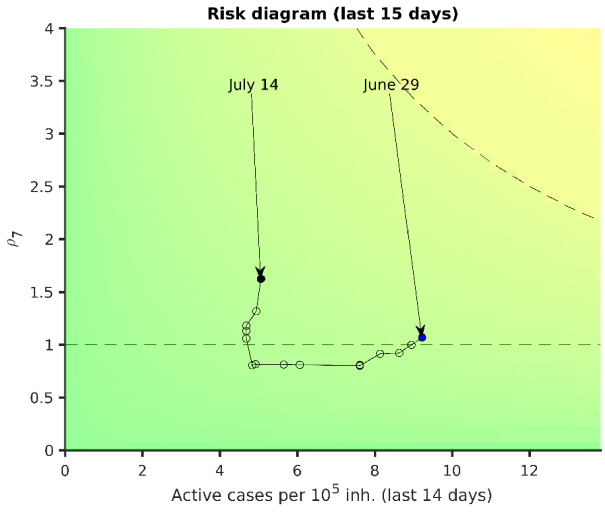




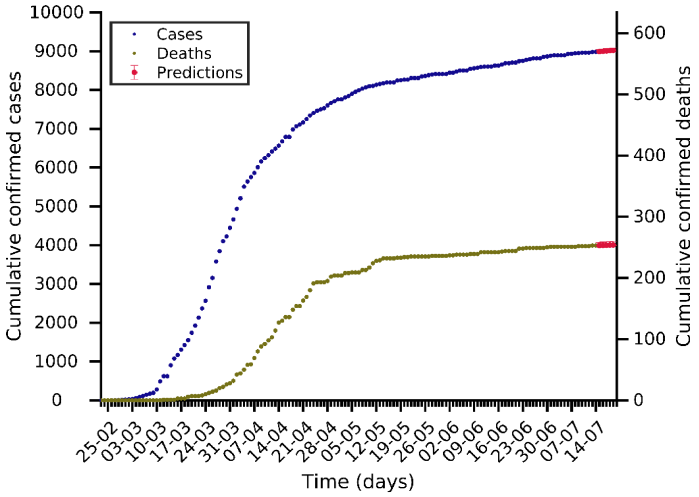


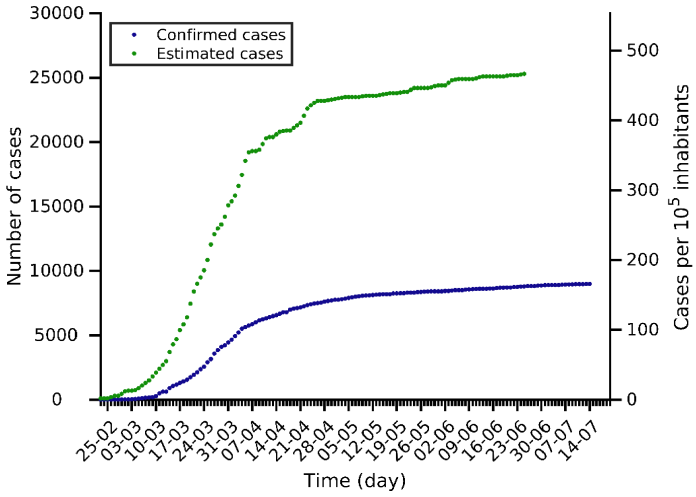


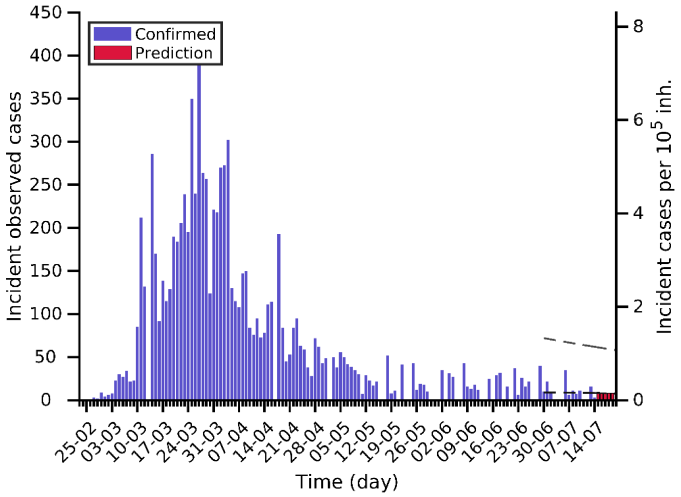


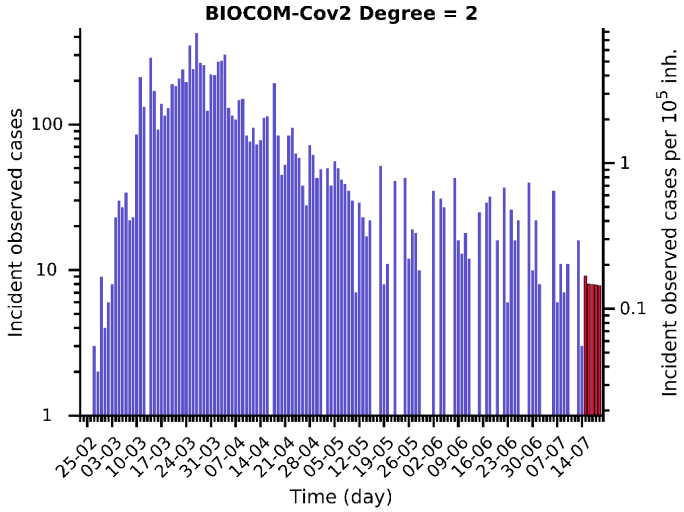


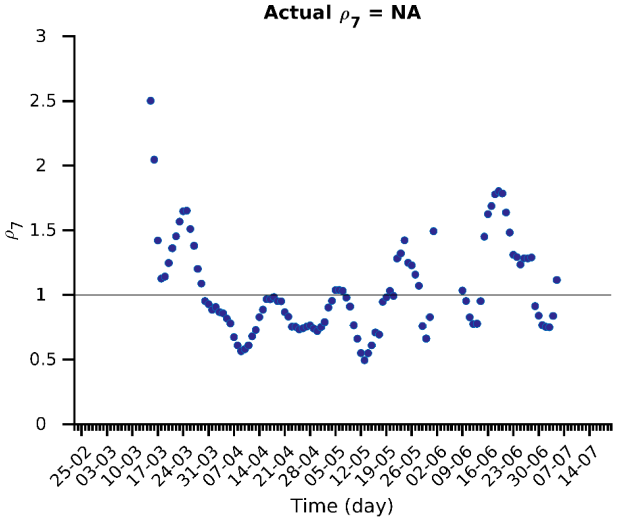
Norway 14-07-2020. Pop: 5.4M. Cumulative incidence: 166/10⁵

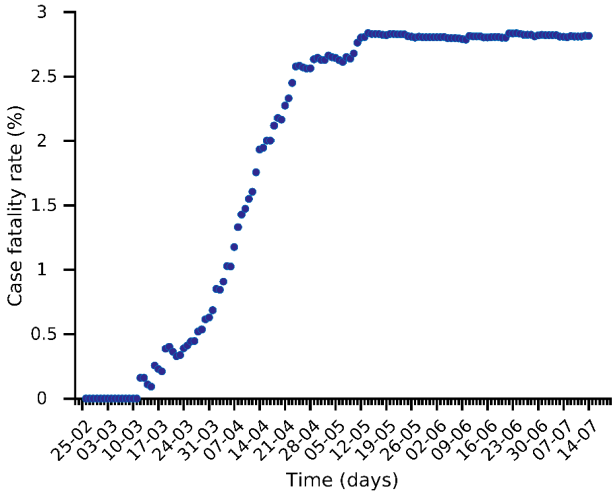


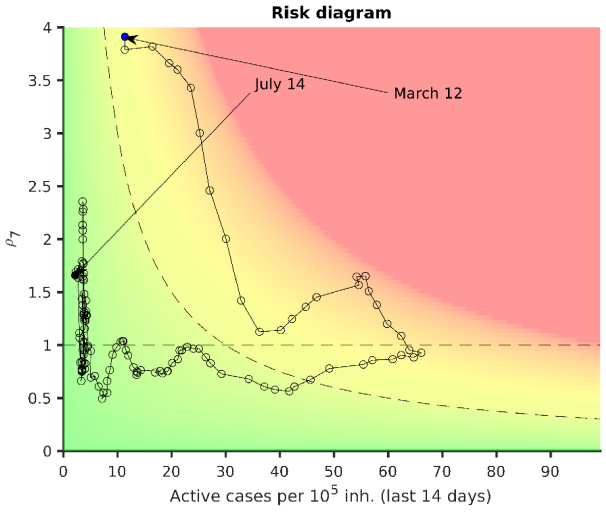


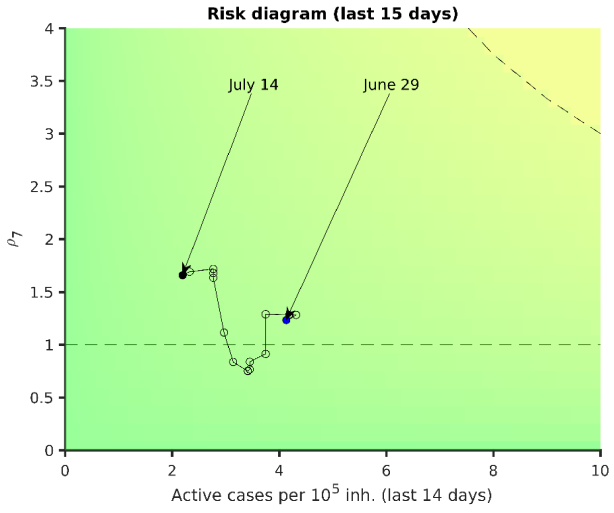




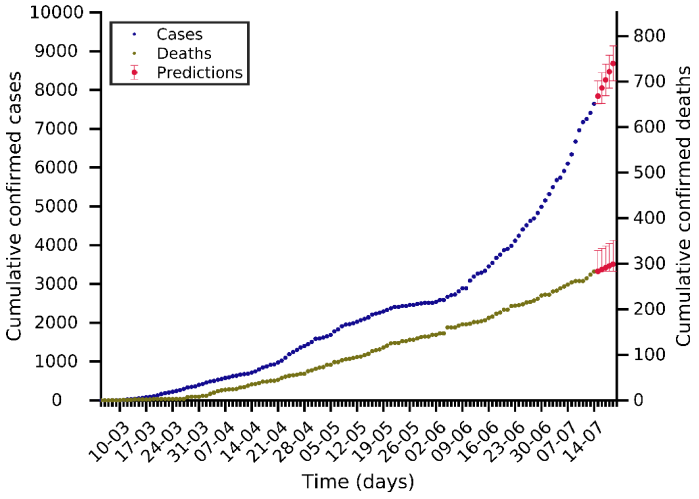


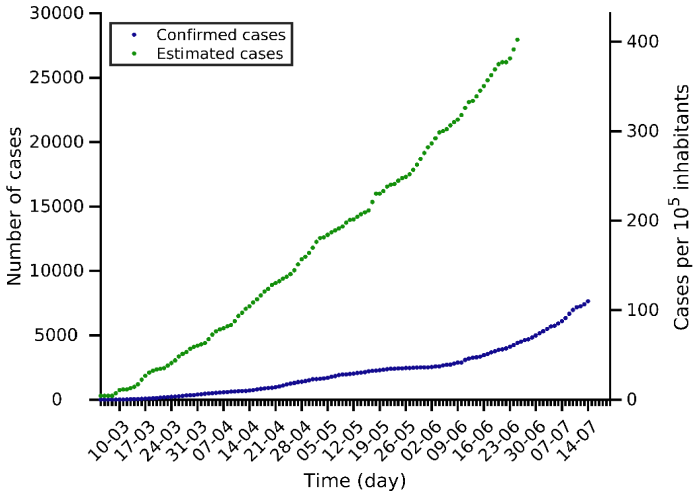


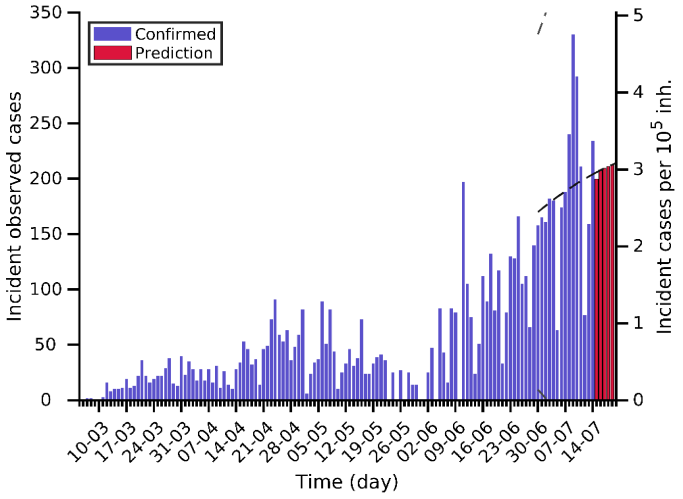


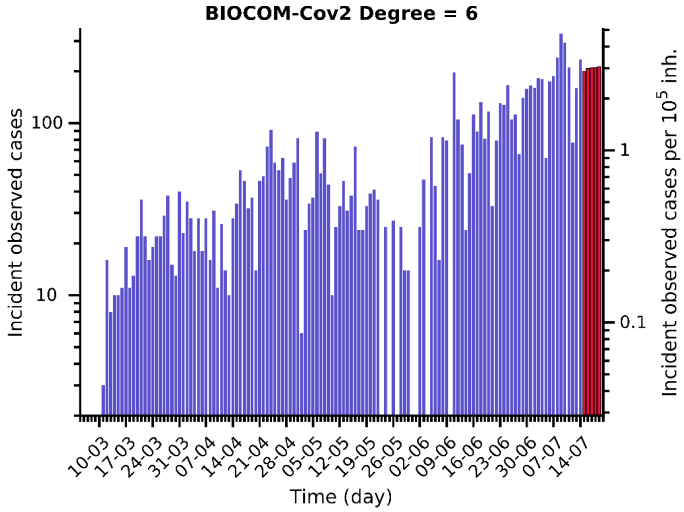


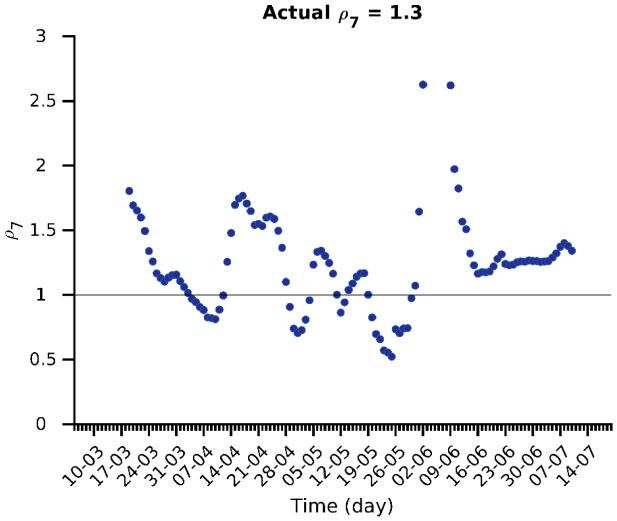
Bulgaria 14-07-2020. Pop: 6.9M. Cumulative incidence: 110/10⁵

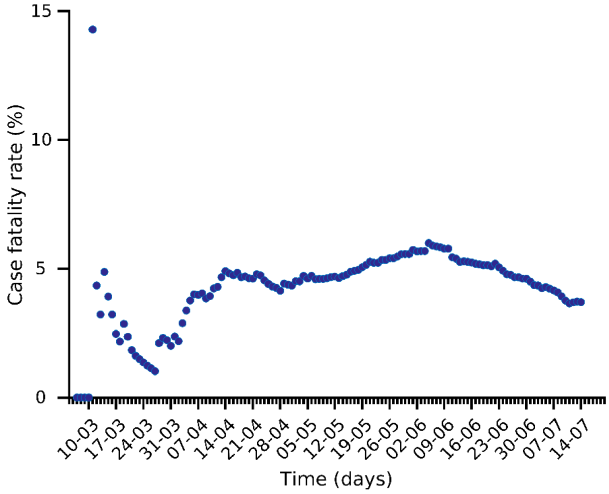


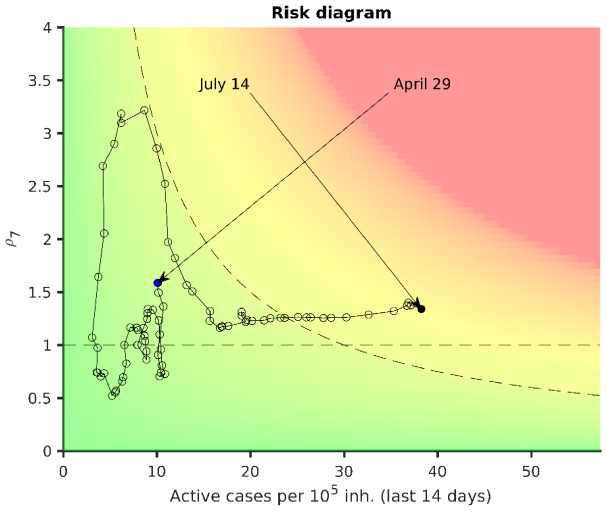


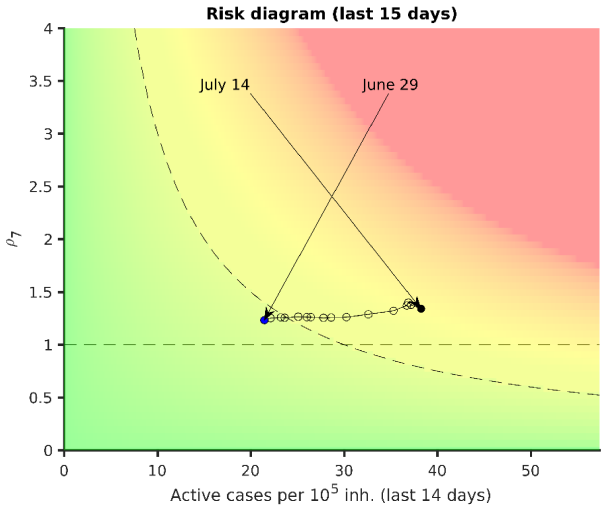




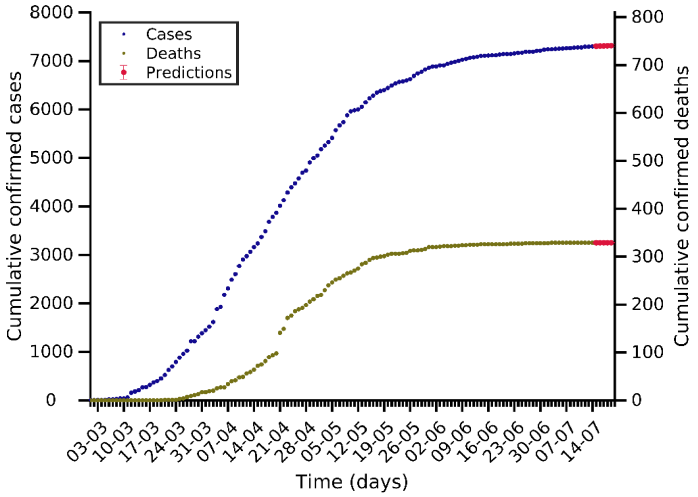


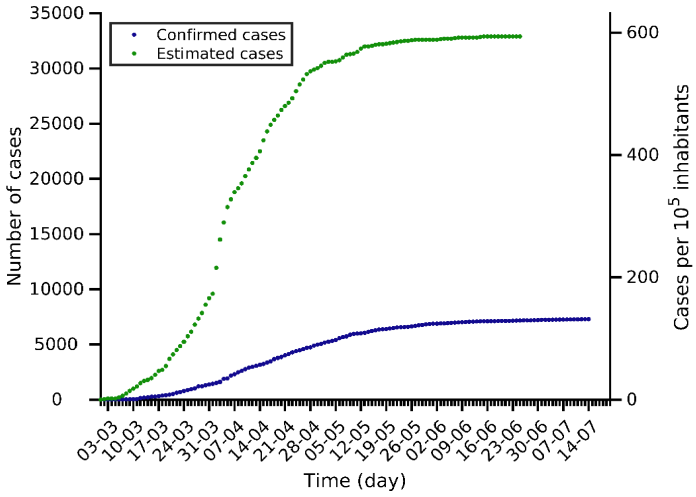


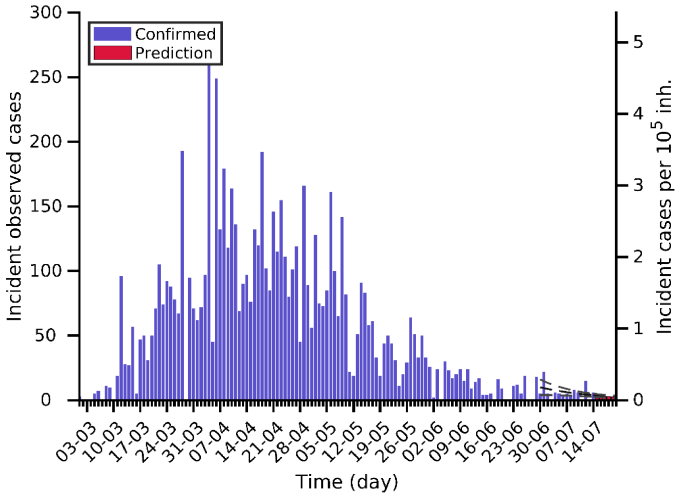


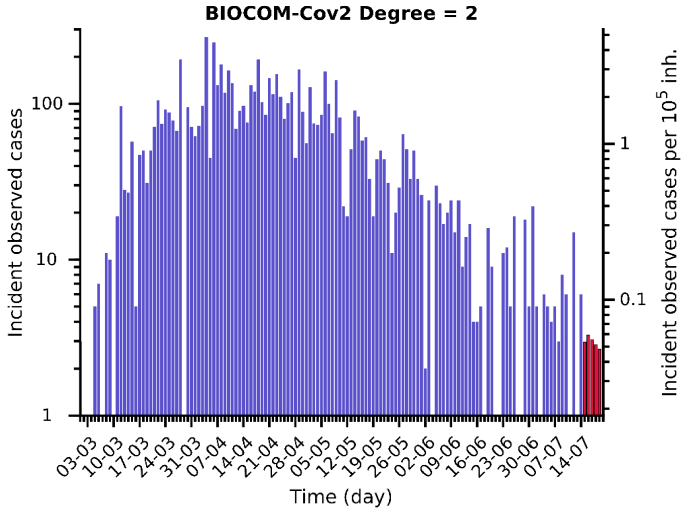


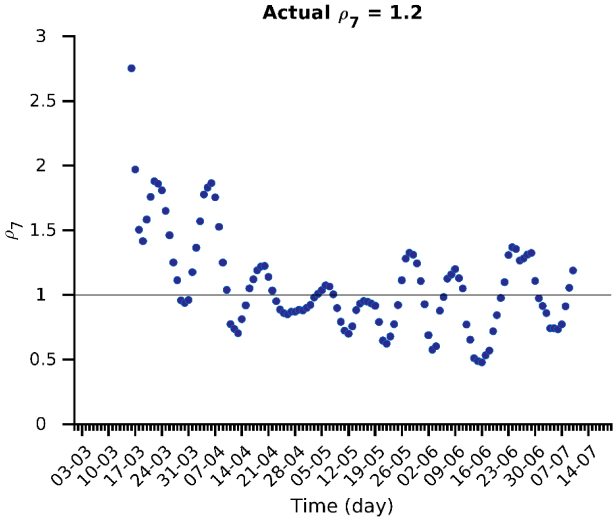
Finland 14-07-2020. Pop: 5.5M. Cumulative incidence: 132/10⁵

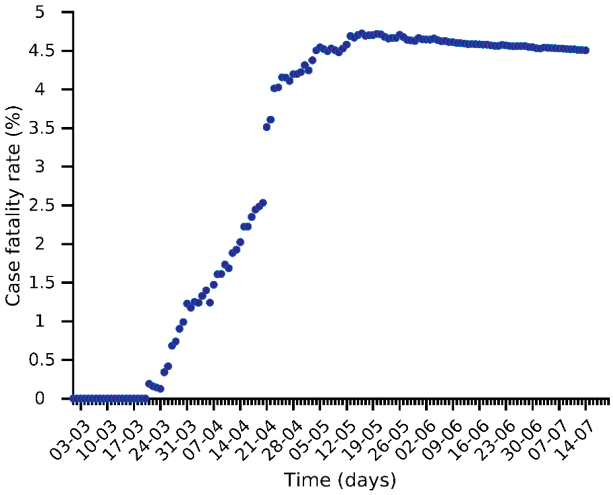


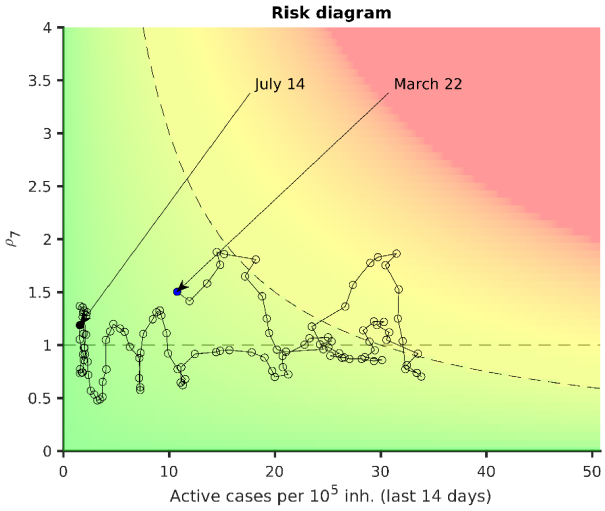


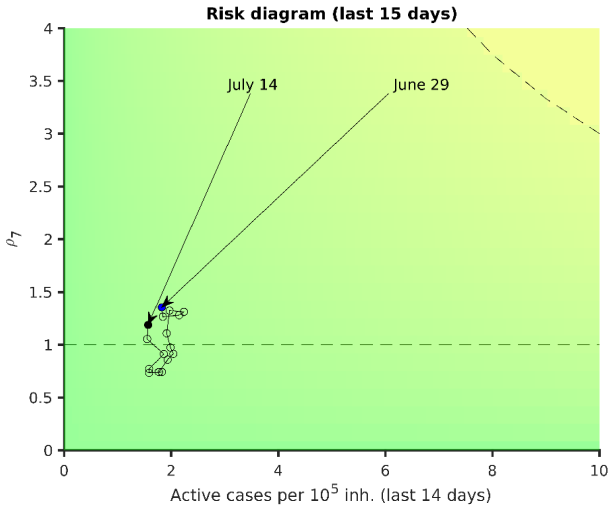




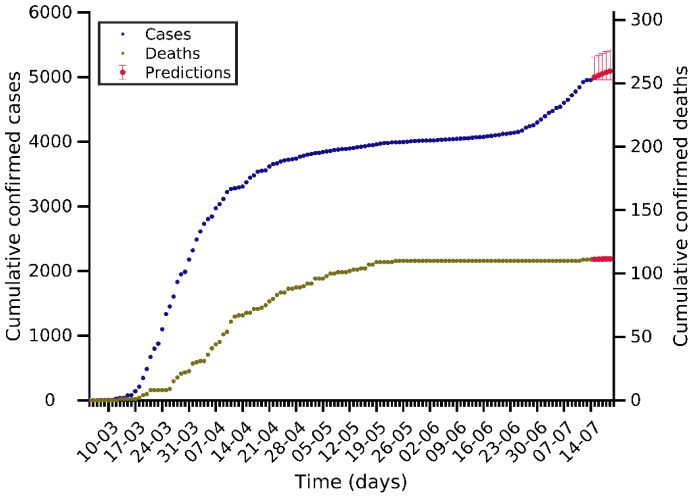


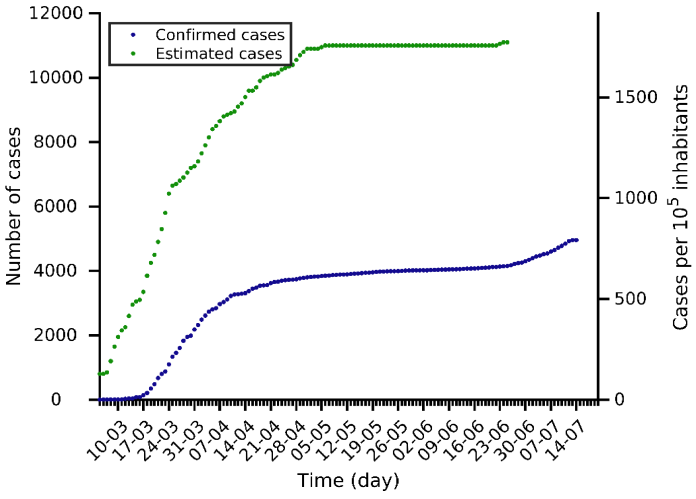


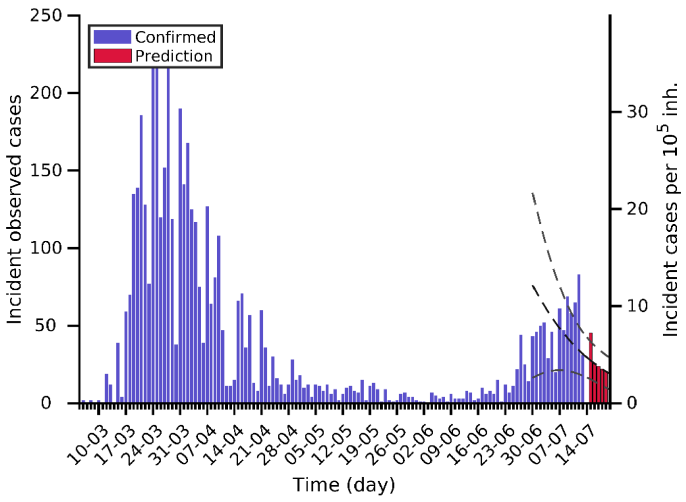


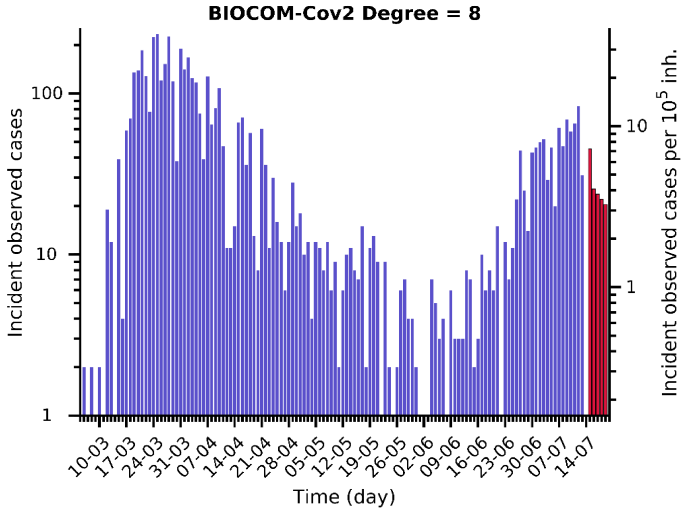


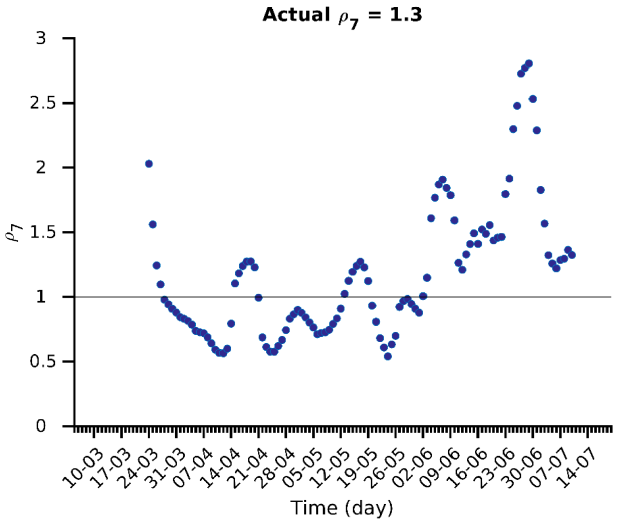
Luxembourg 14-07-2020. Pop: 0.6M. Cumulative incidence: 792/10⁵

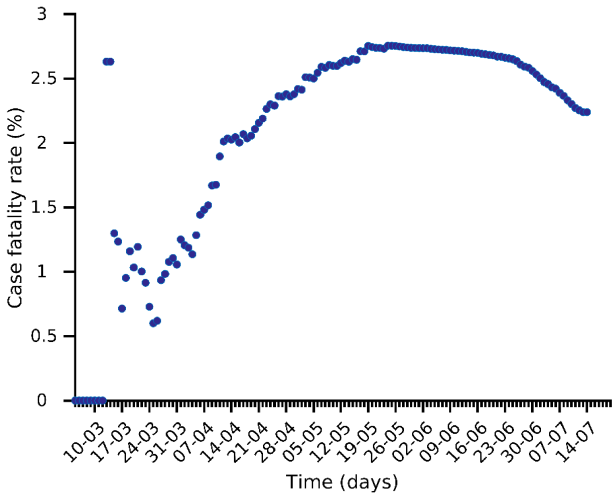


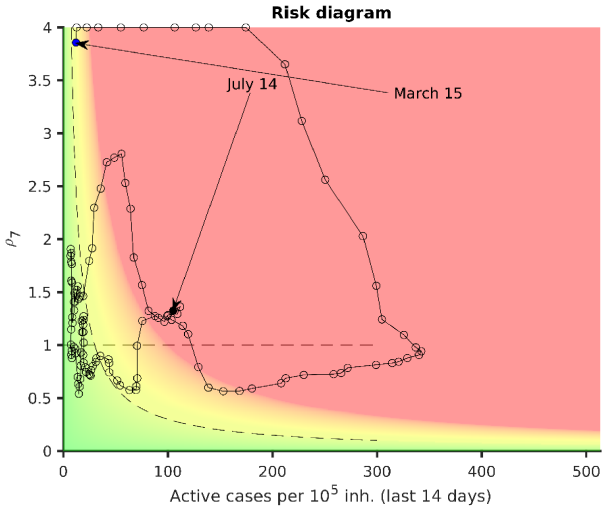


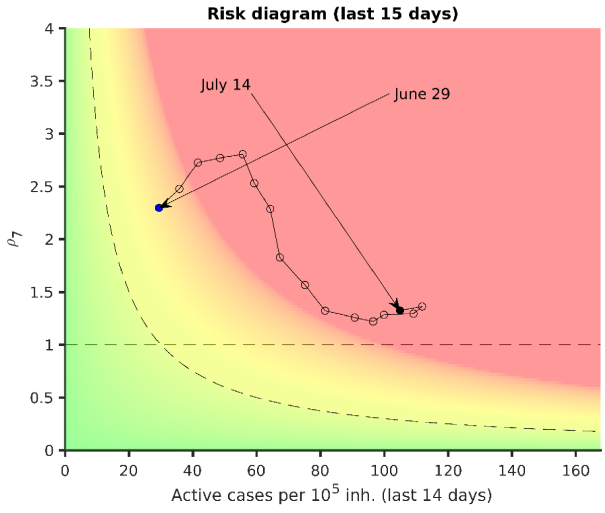




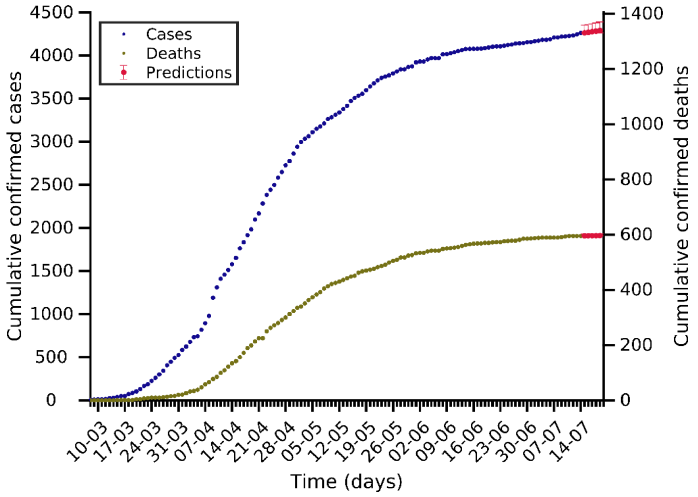


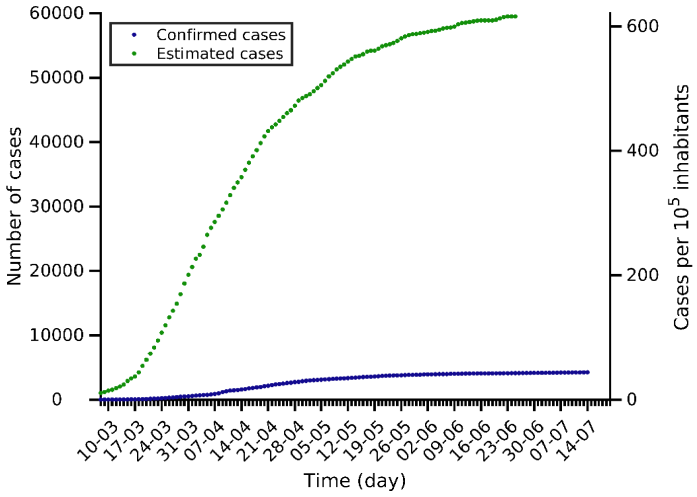


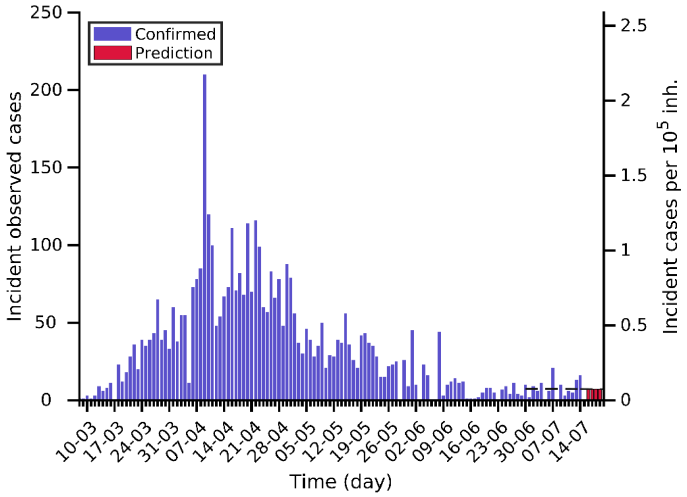


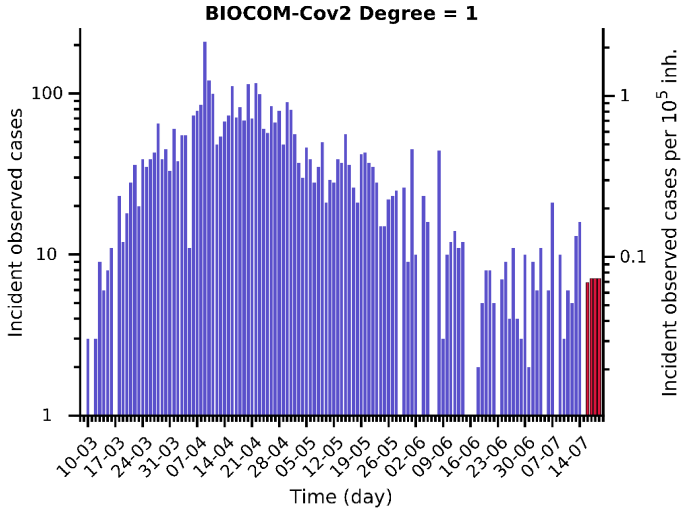


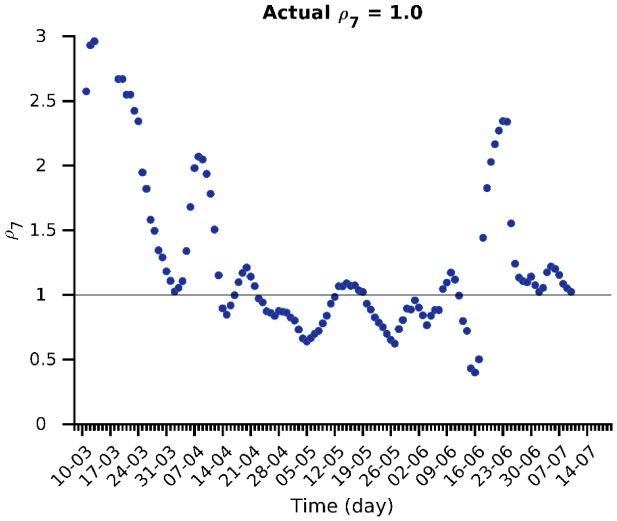
Hungary 14-07-2020. Pop: 9.7M. Cumulative incidence: 44/10⁵

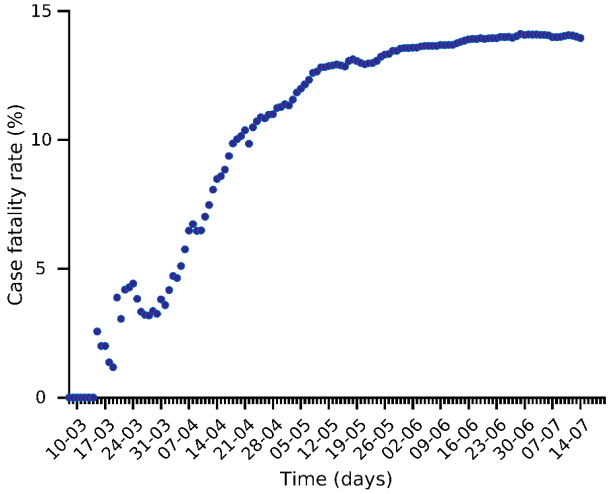


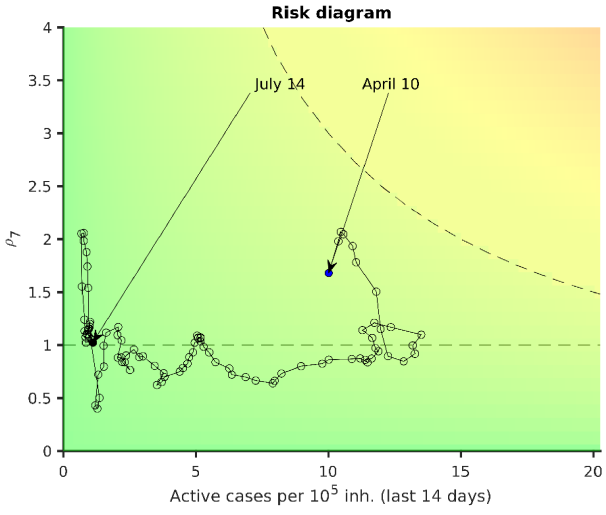


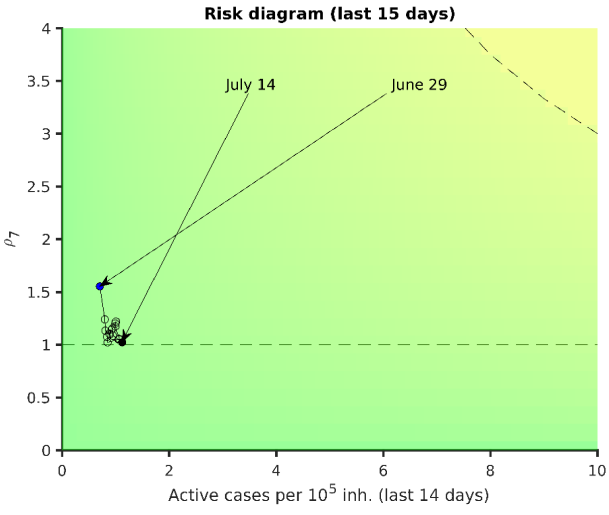




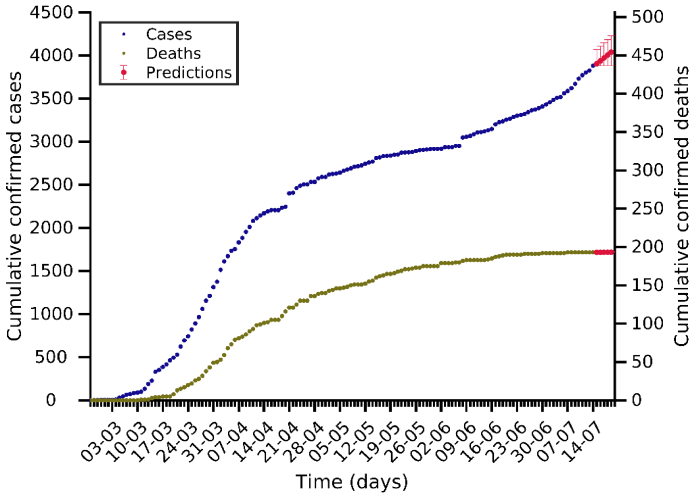


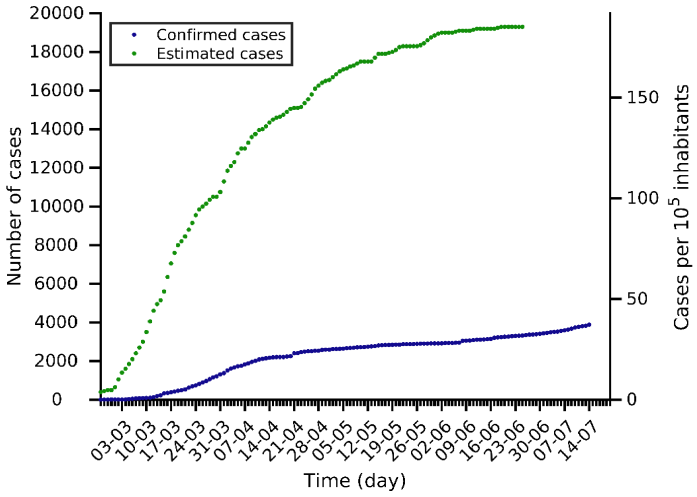


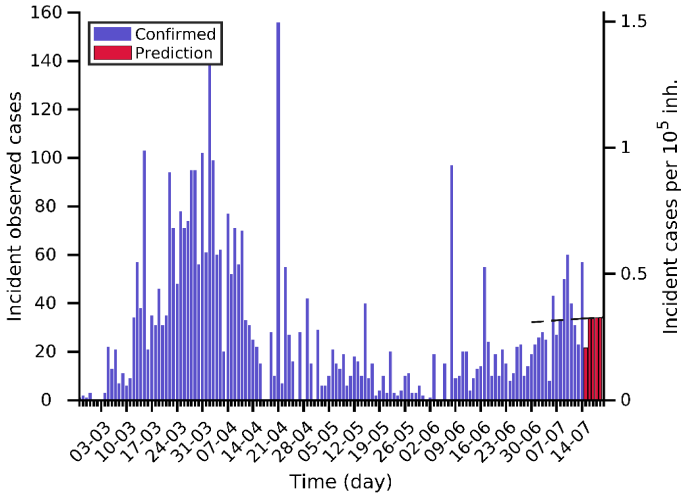


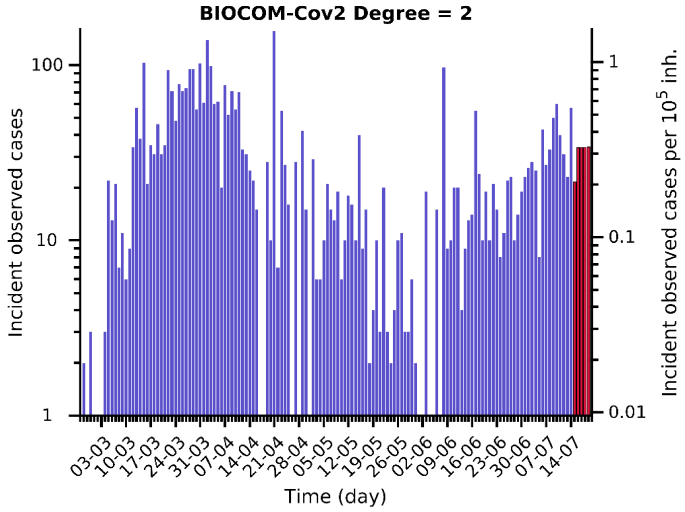


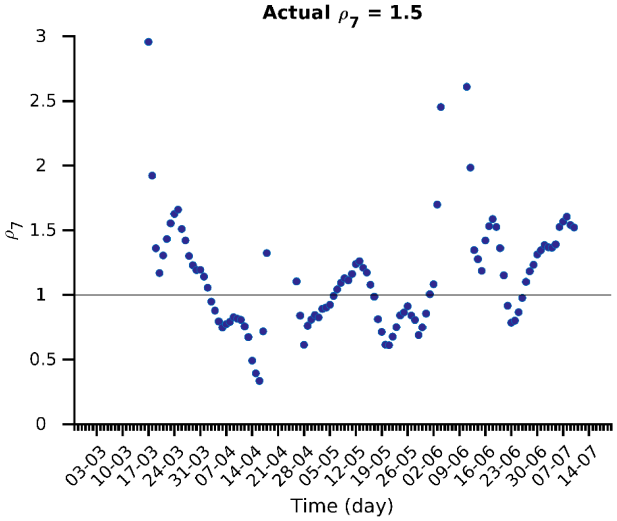
Greece 14-07-2020. Pop: 10.4M. Cumulative incidence: 37/10^5

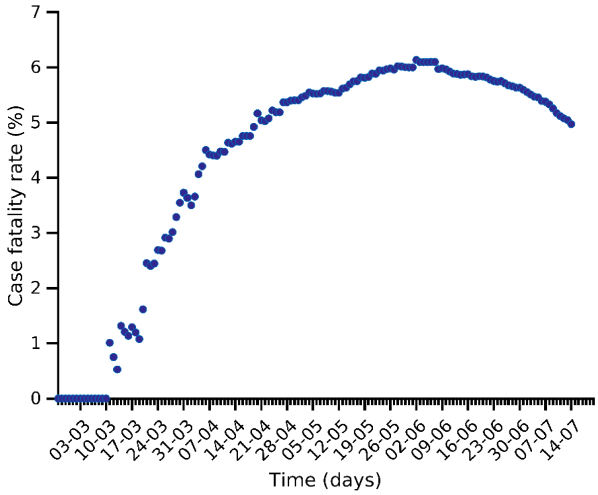


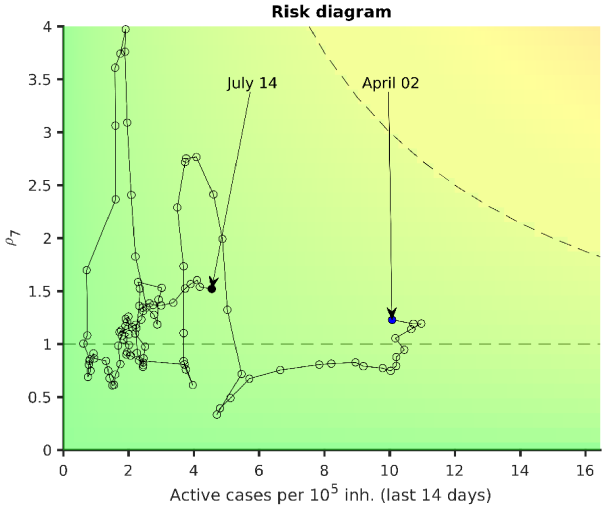


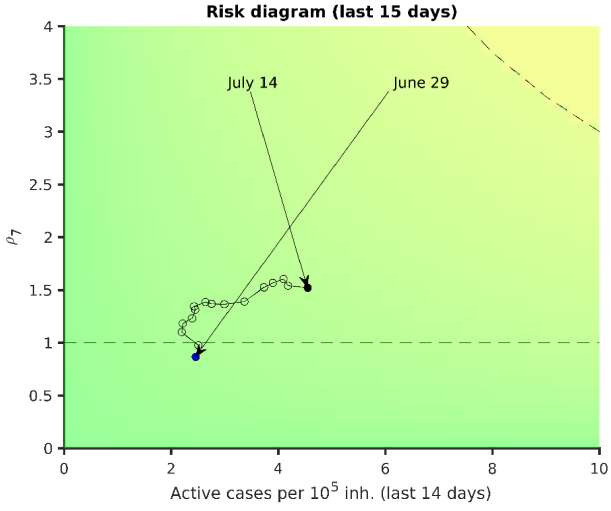




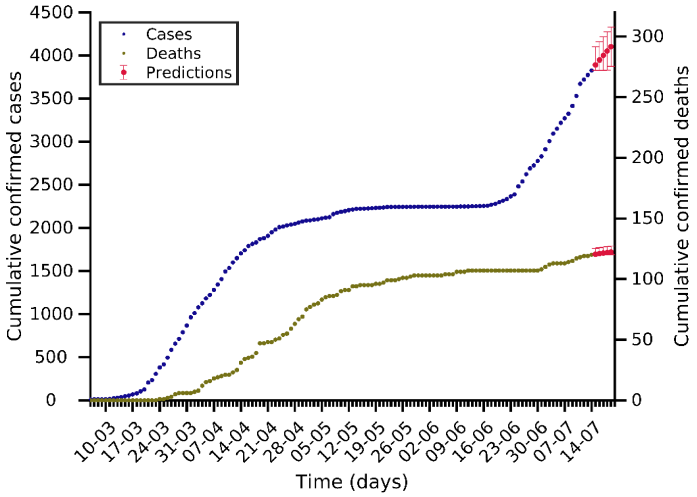


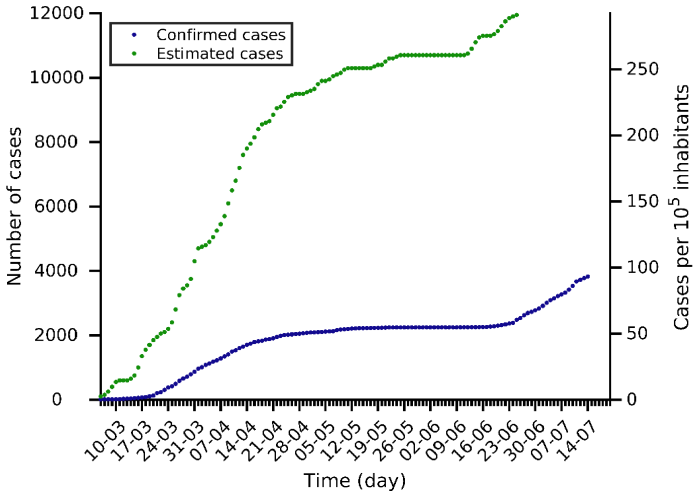


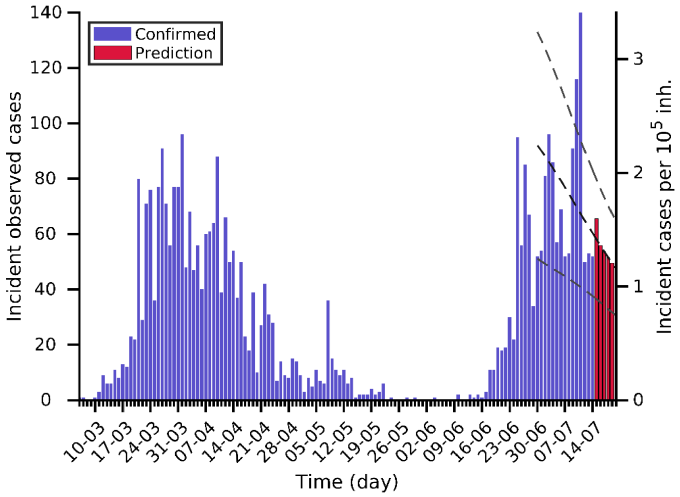


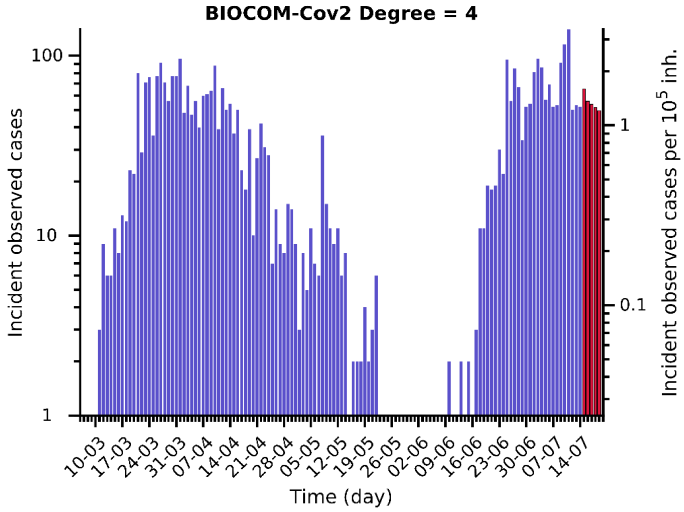


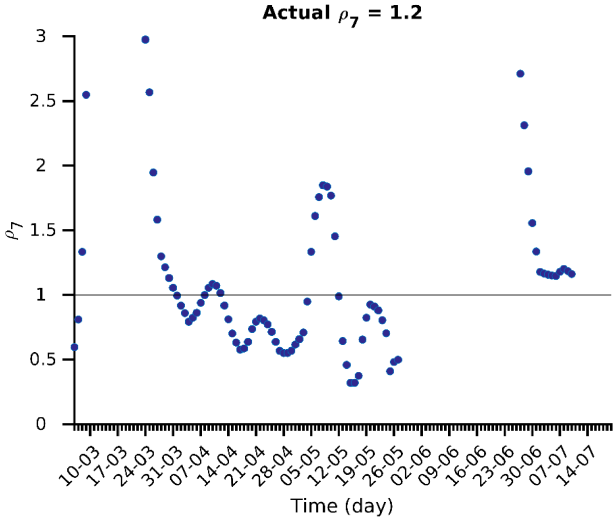
Croatia 14-07-2020. Pop: 4.1M. Cumulative incidence: 93/10⁵

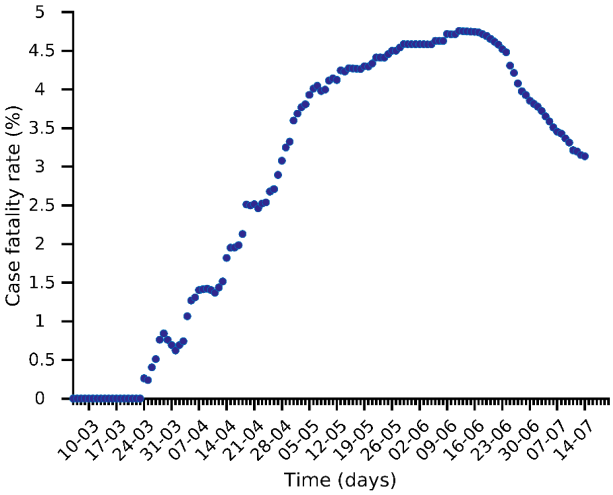


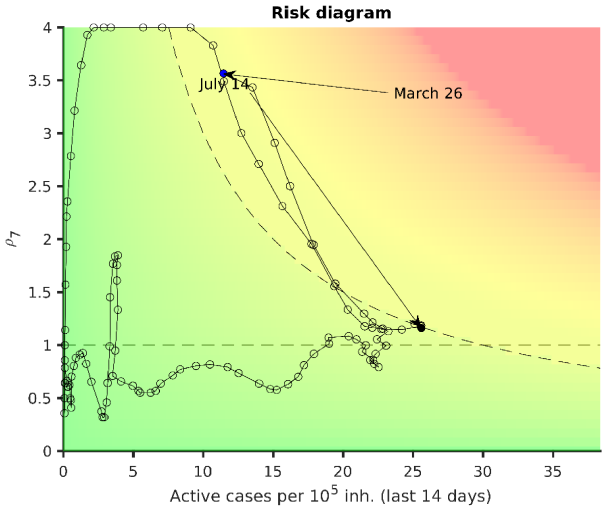


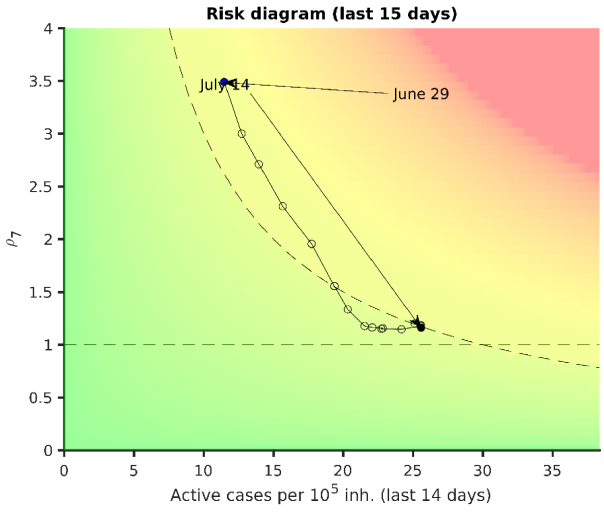




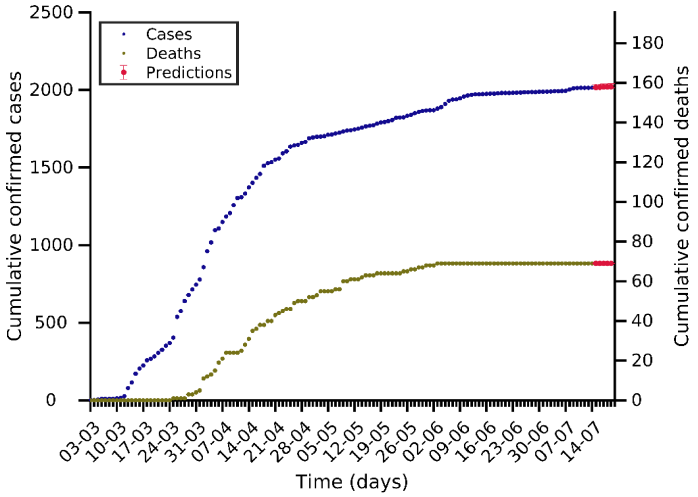


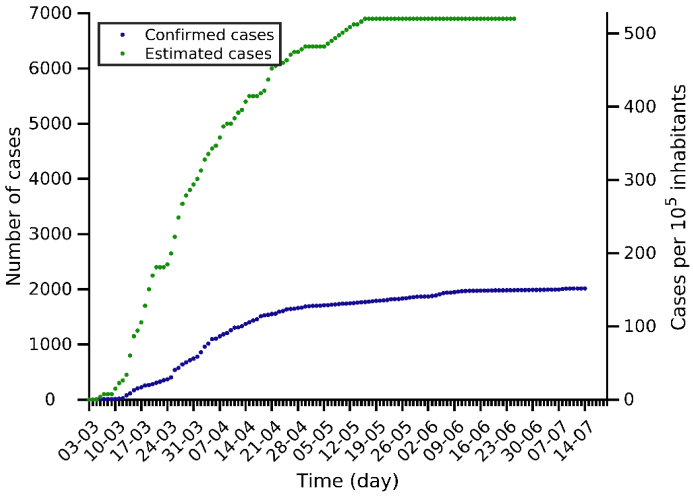


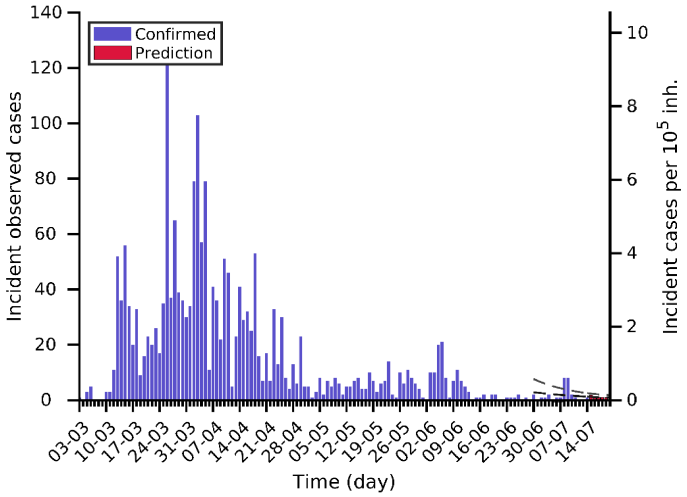


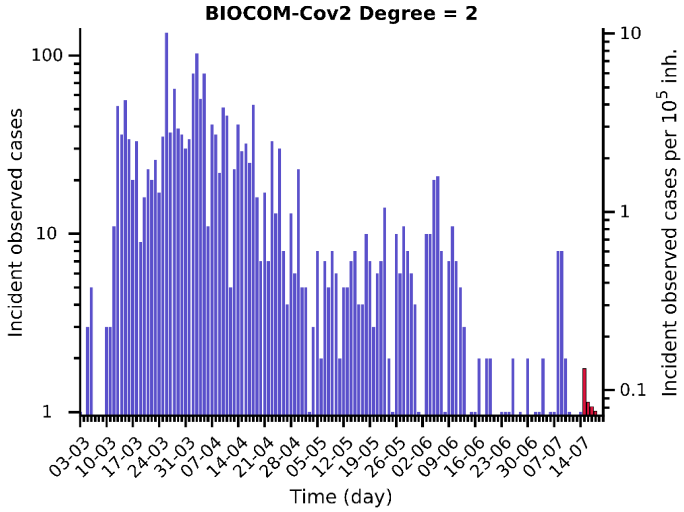


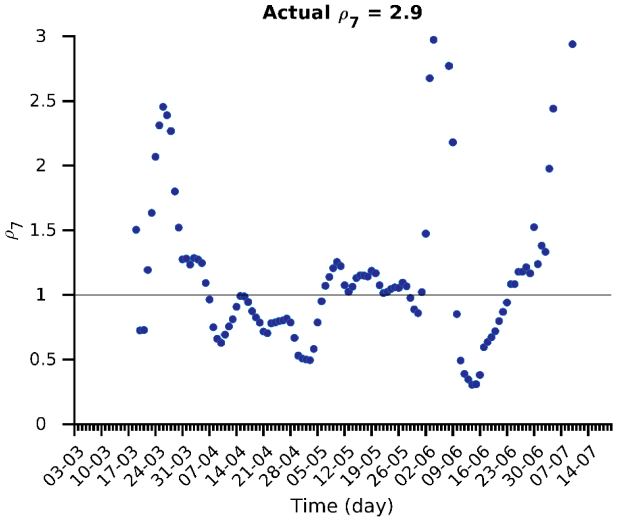
Estonia 14-07-2020. Pop: 1.3M. Cumulative incidence: 152/10⁵

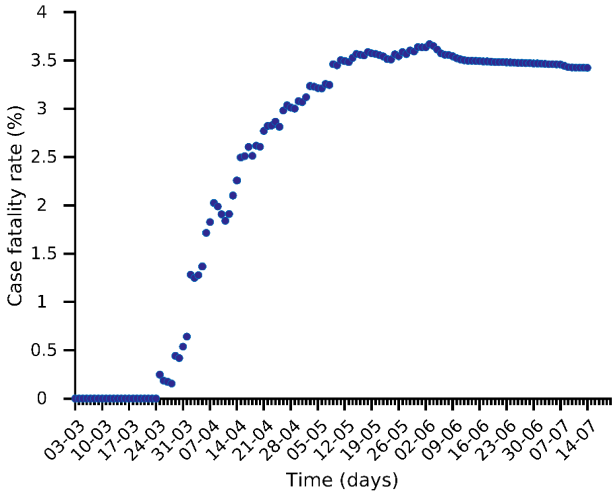


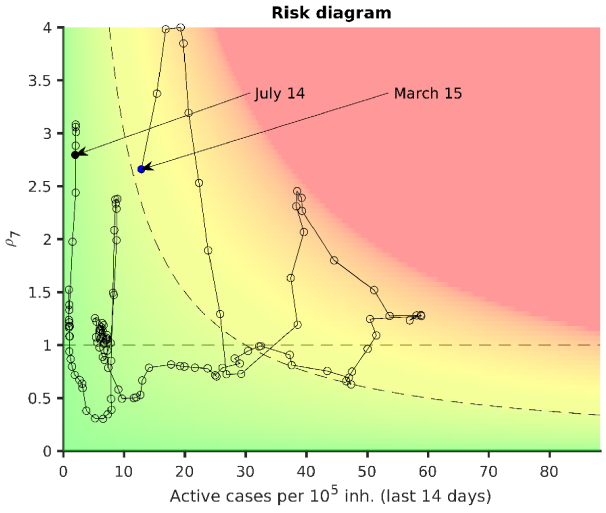


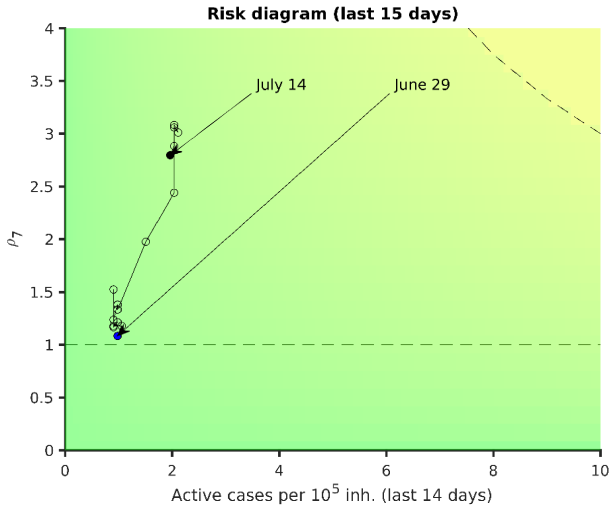




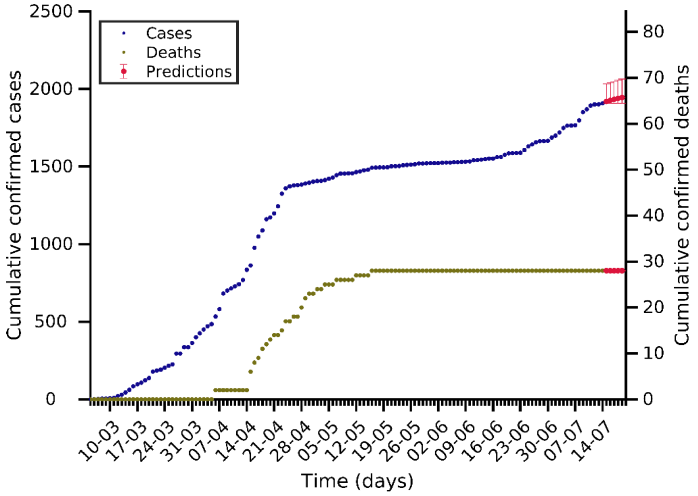


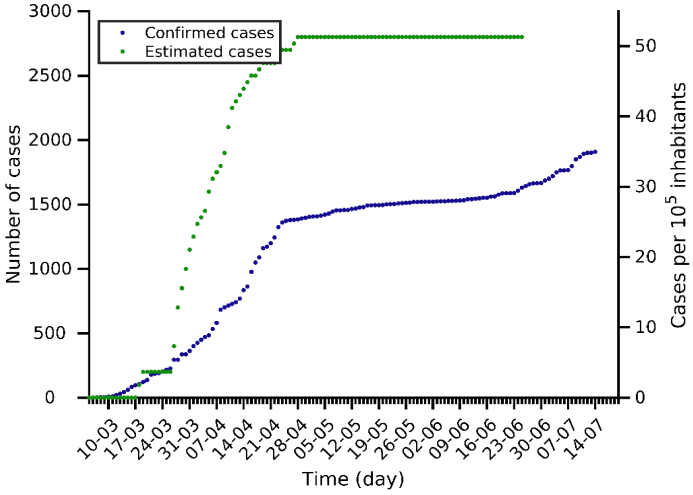


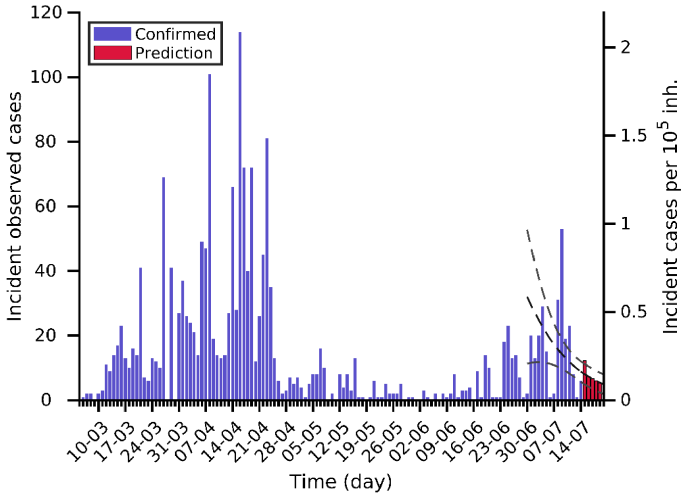


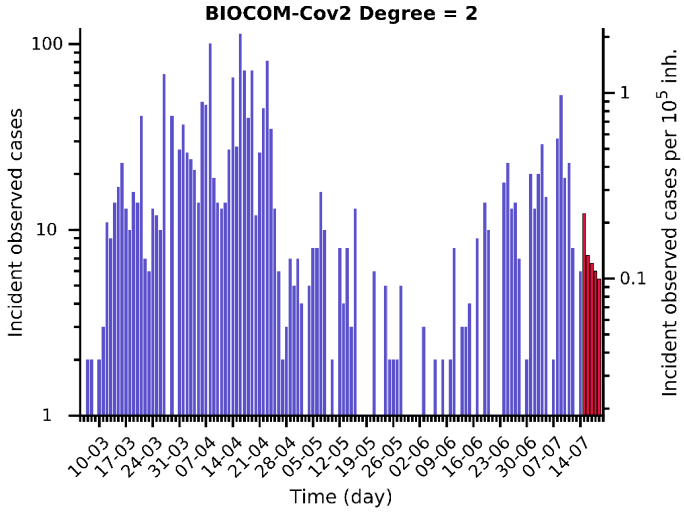


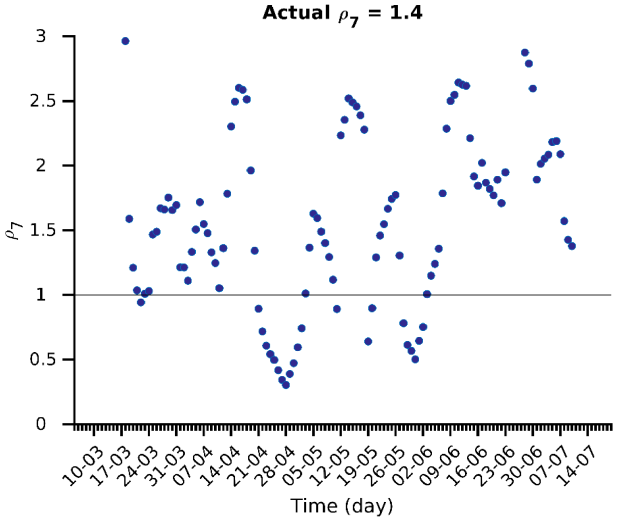
Slovakia 14-07-2020. Pop: 5.5M. Cumulative incidence: 35/10⁵

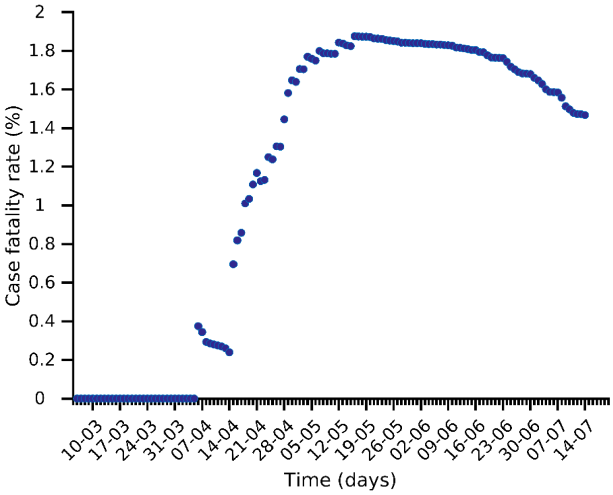


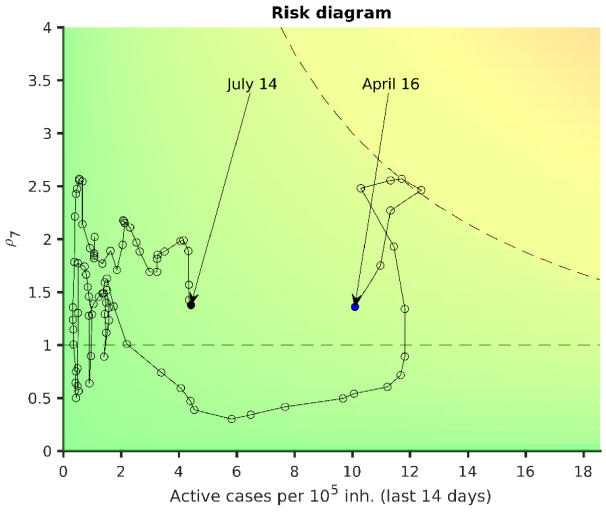


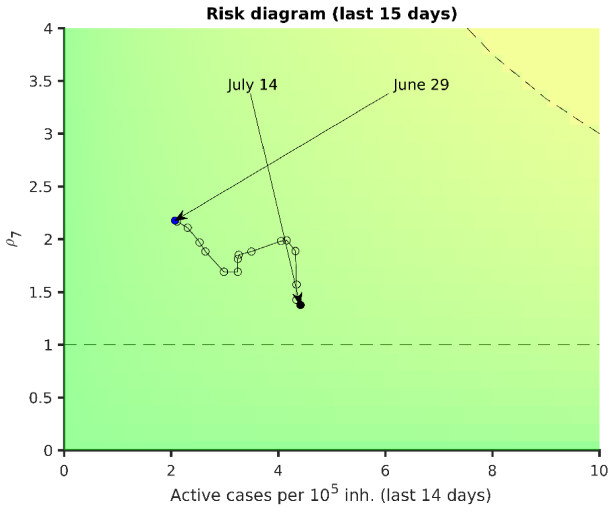




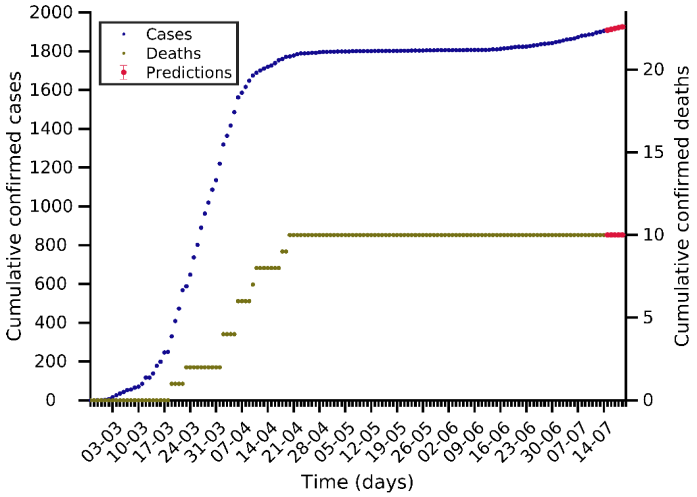


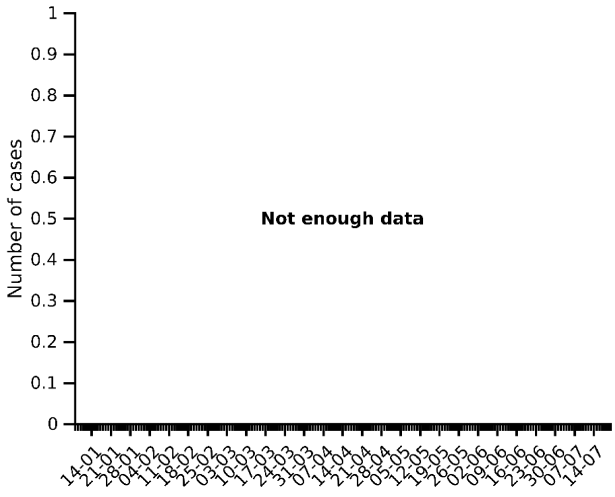


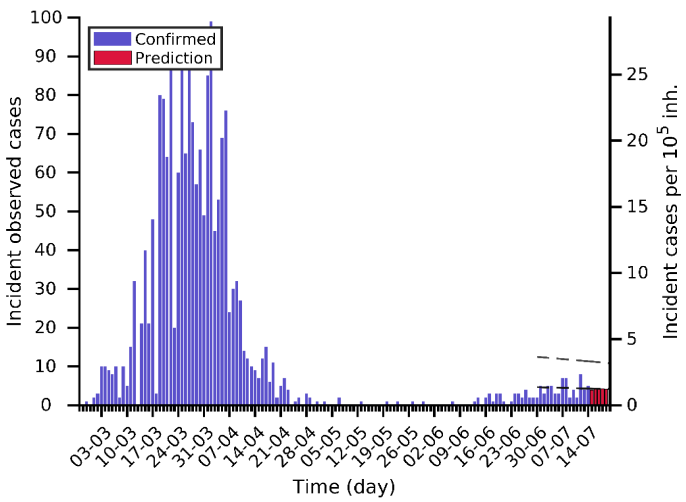


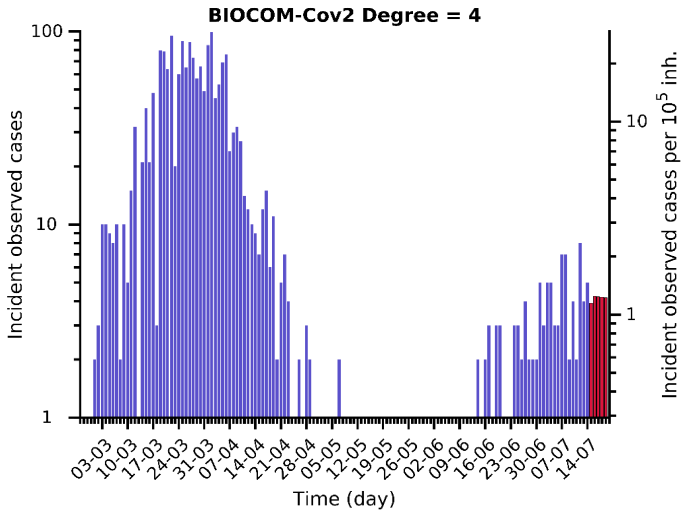


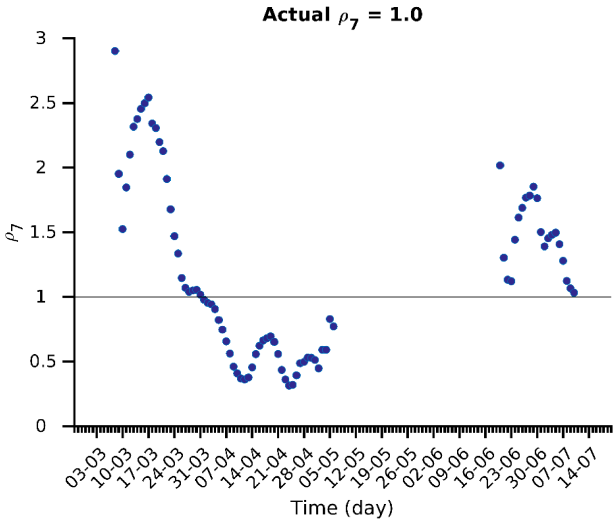
Iceland 14-07-2020. Pop: 0.3M. Cumulative incidence: 558/10⁵

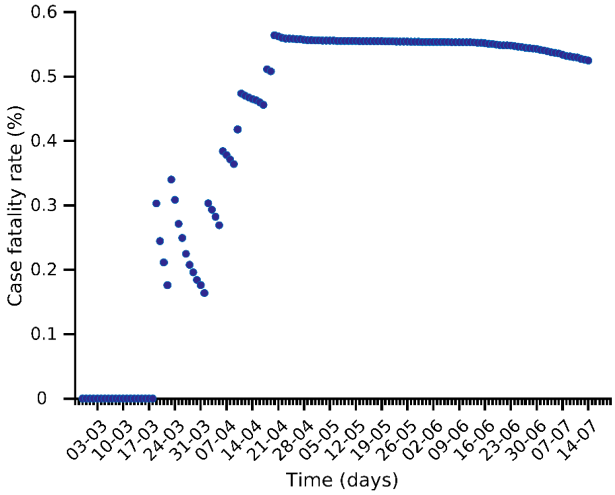


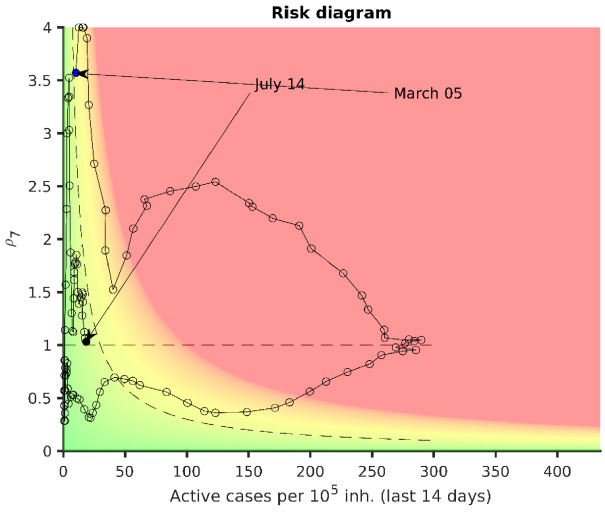


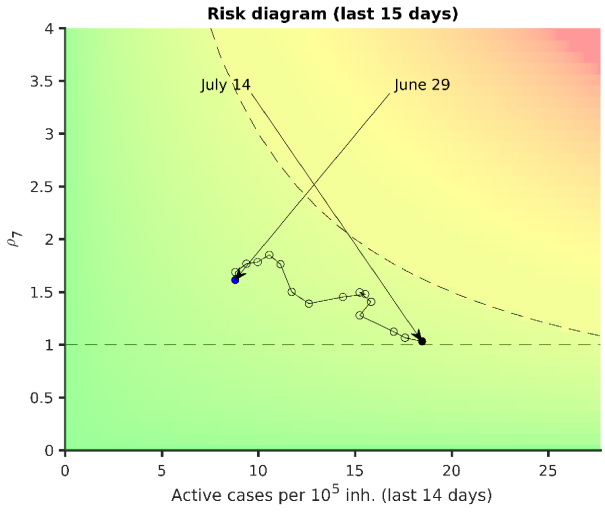




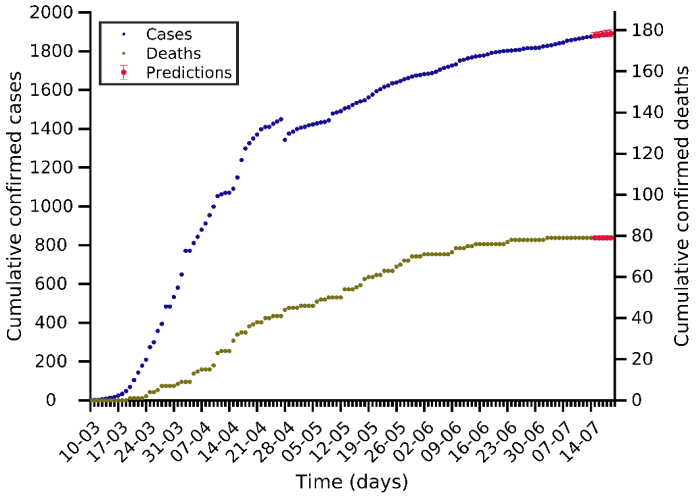


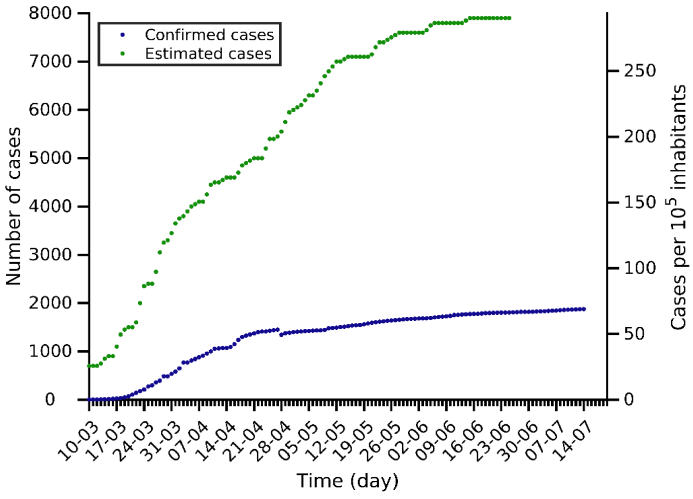


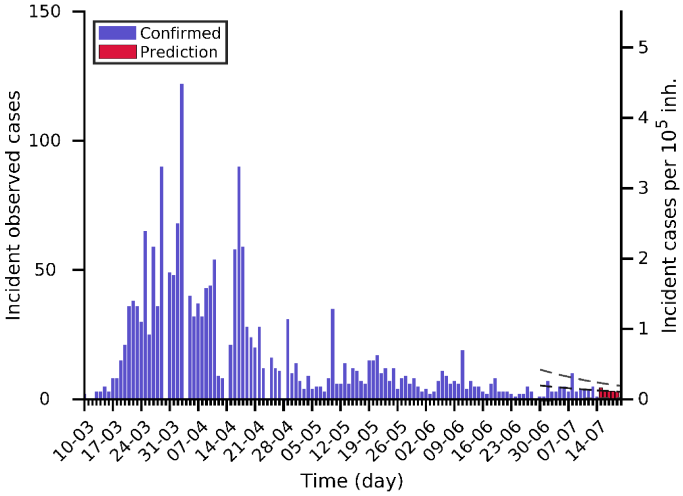


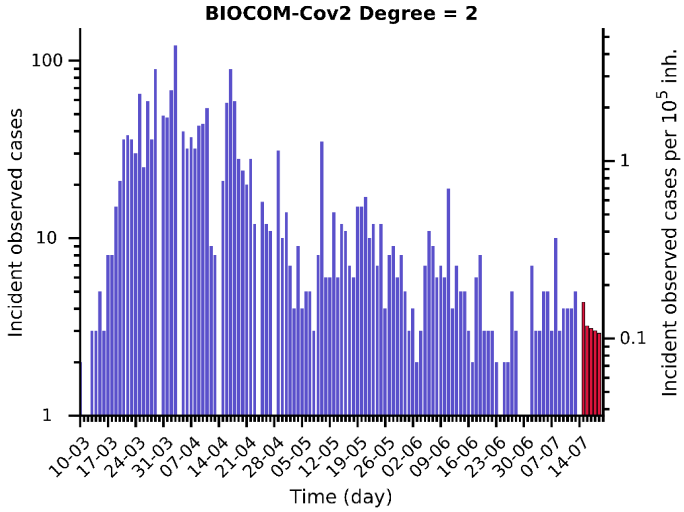


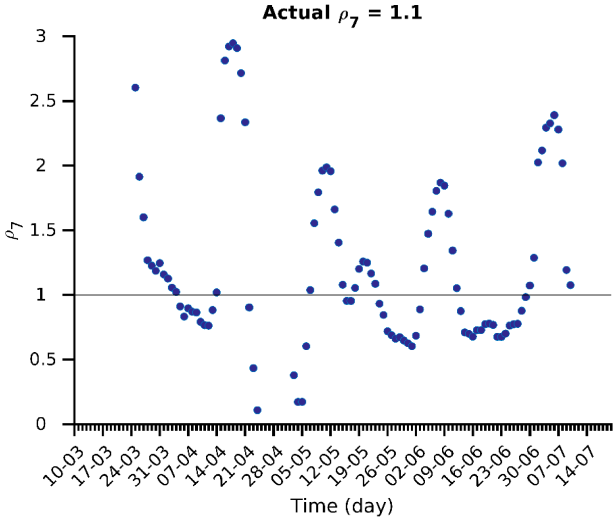
Lithuania 14-07-2020. Pop: 2.7M. Cumulative incidence: 69/10^5

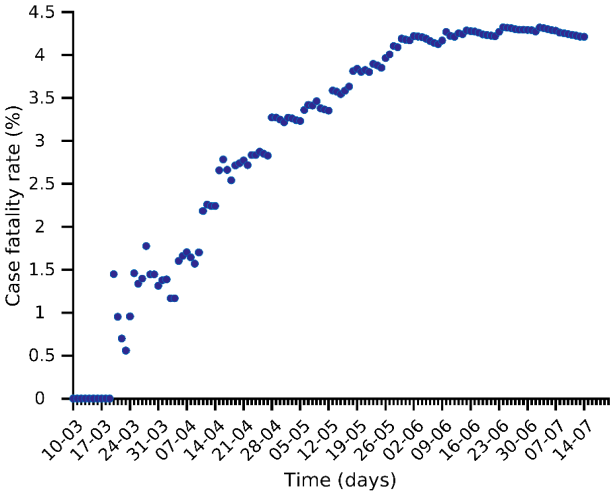


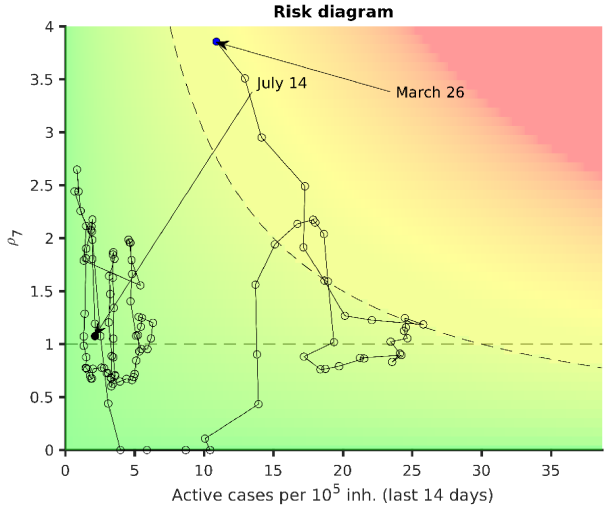


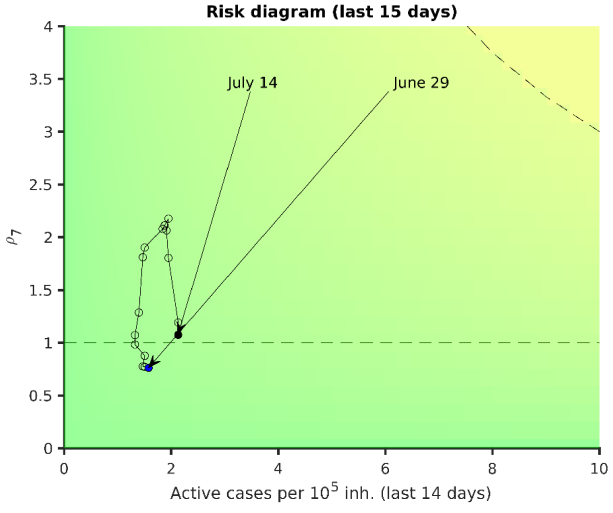




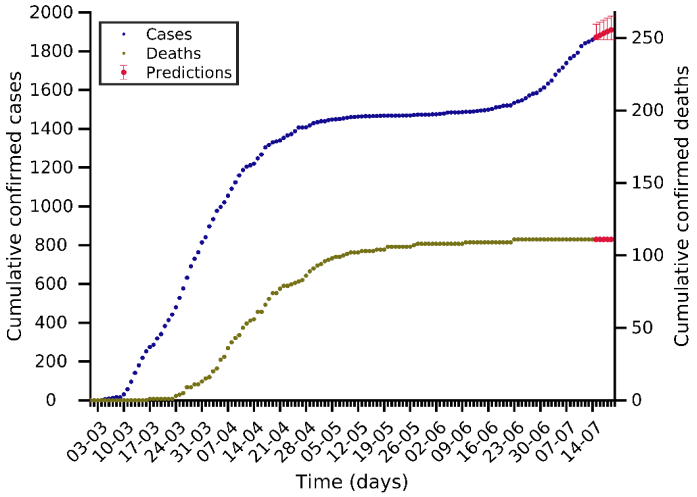


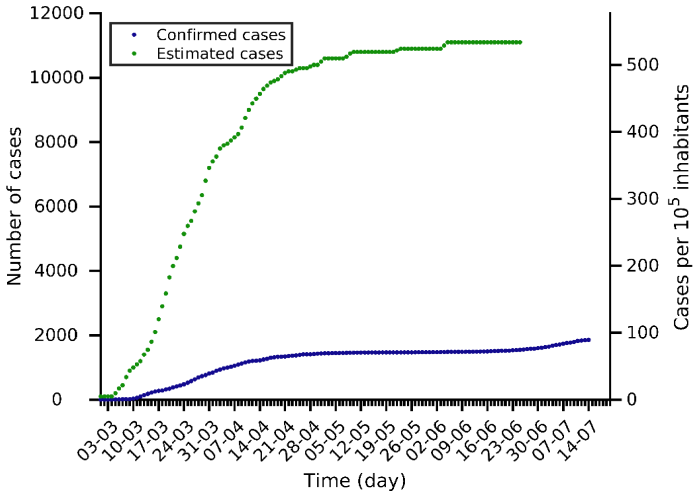


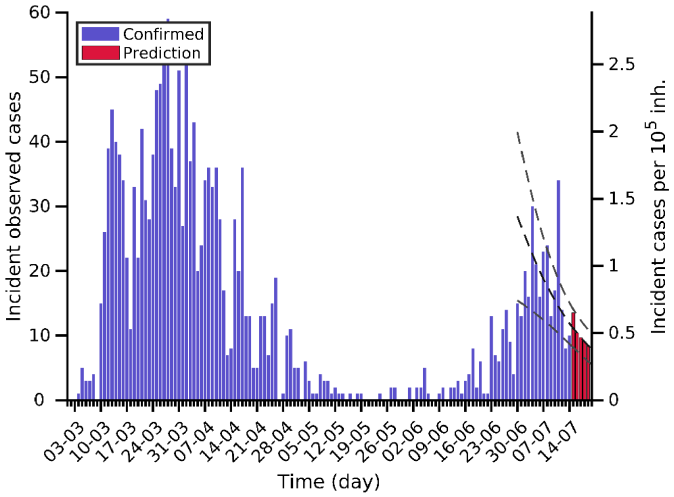


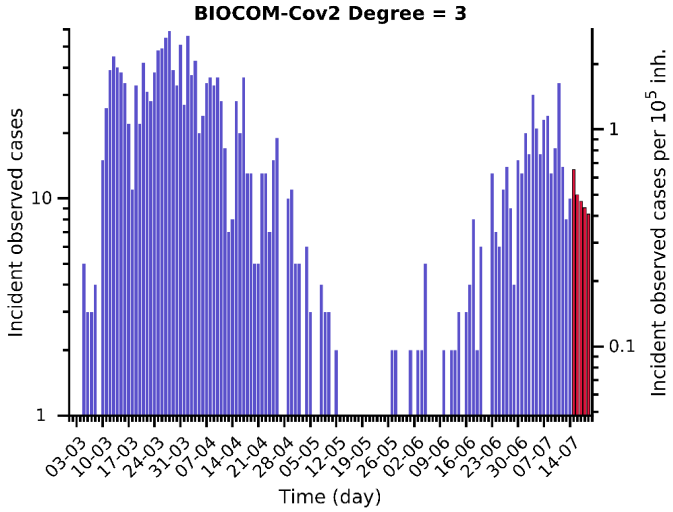


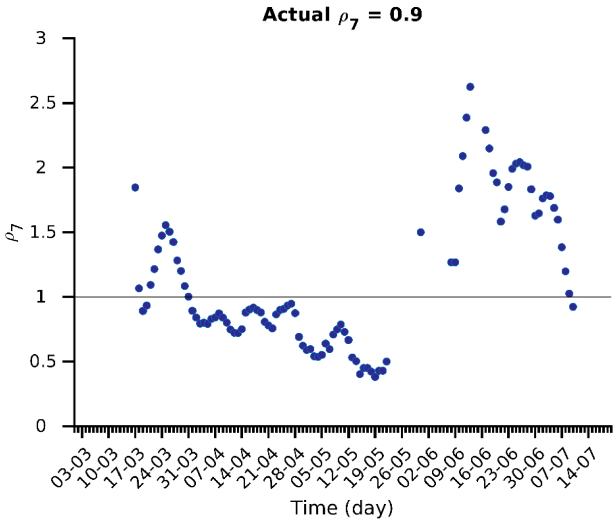
Slovenia 14-07-2020. Pop: 2.1M. Cumulative incidence: $89/10^5$

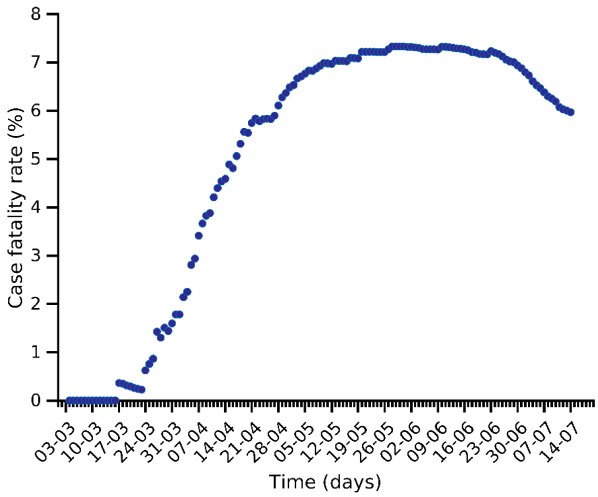


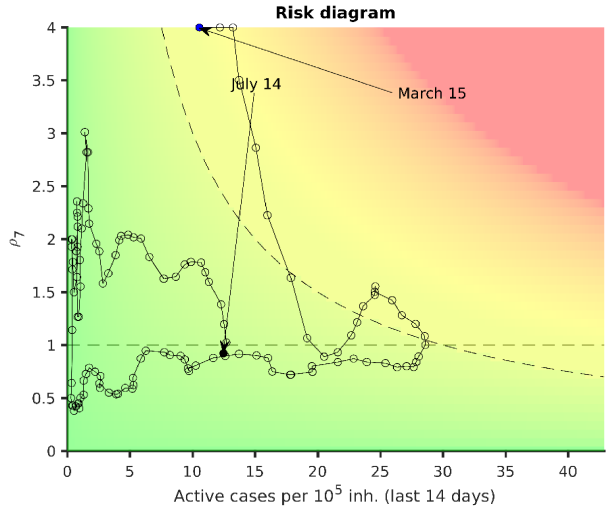


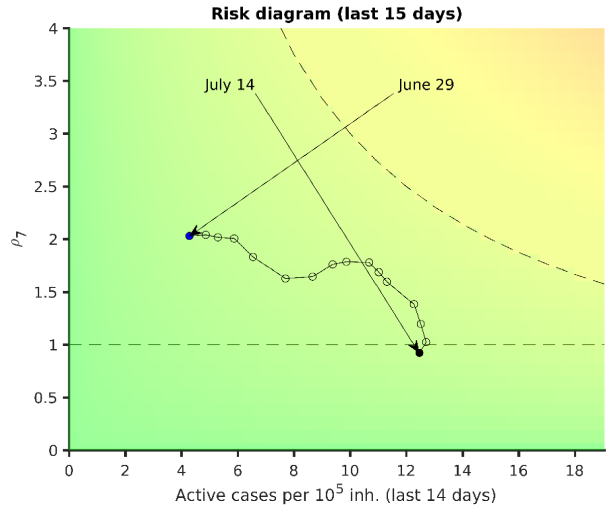




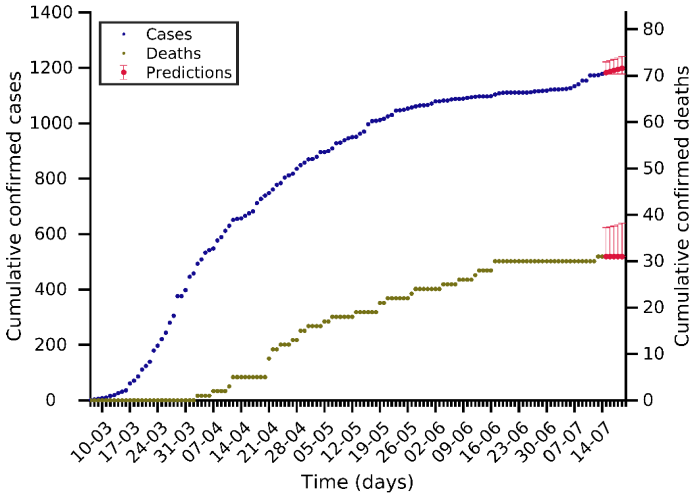


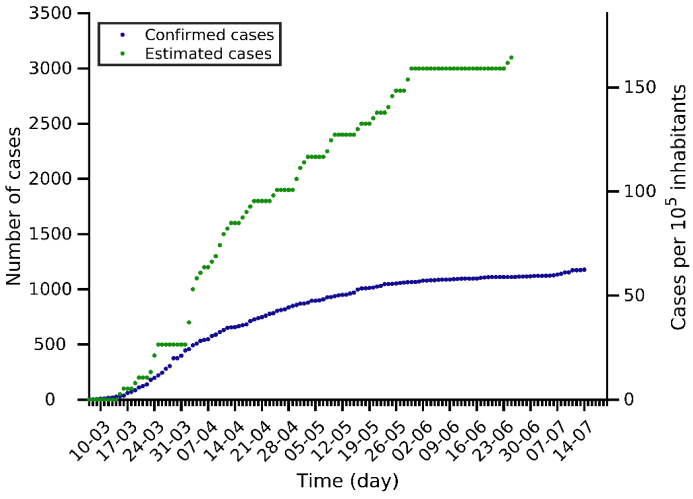


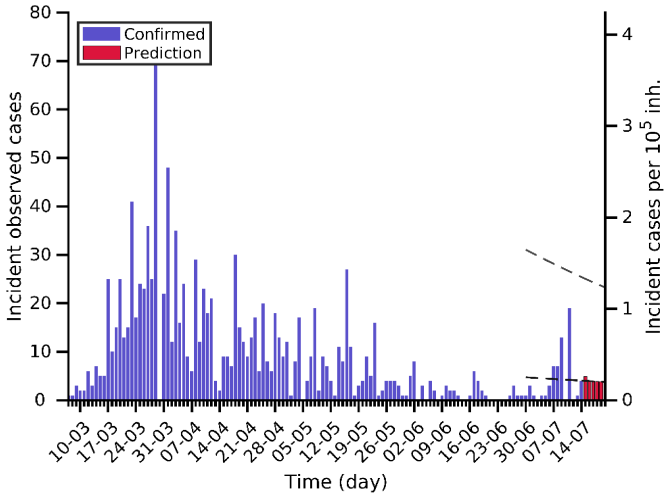


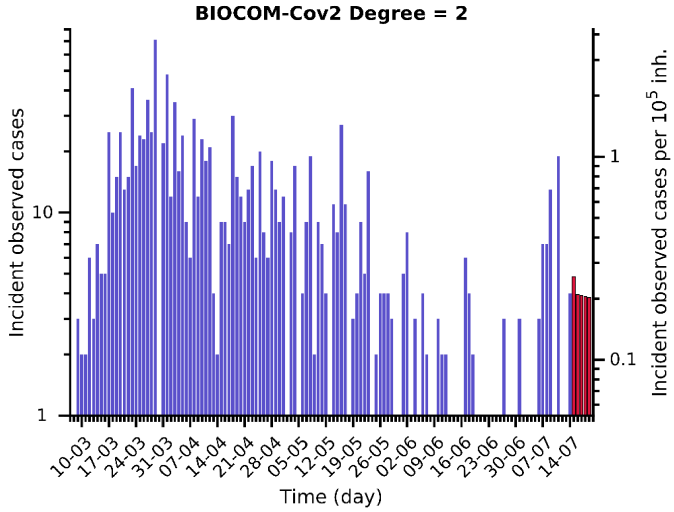


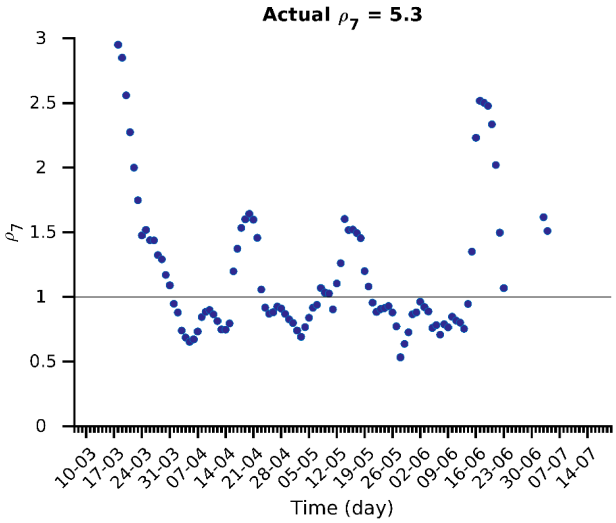
Latvia 14-07-2020. Pop: 1.9M. Cumulative incidence: 62/10^5

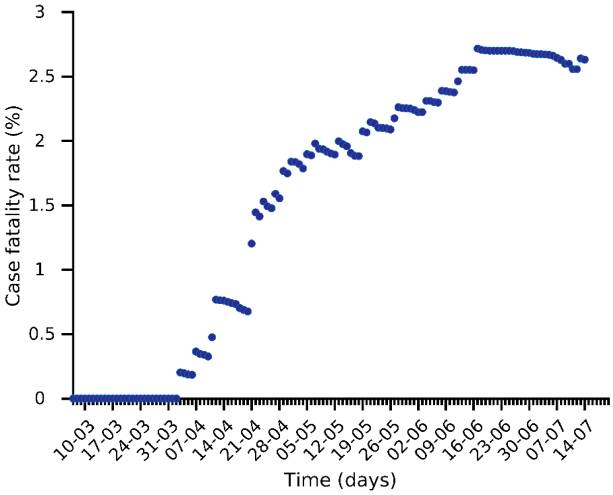


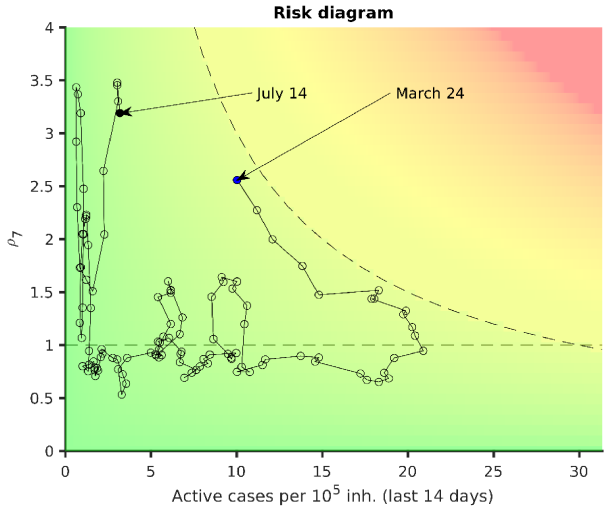


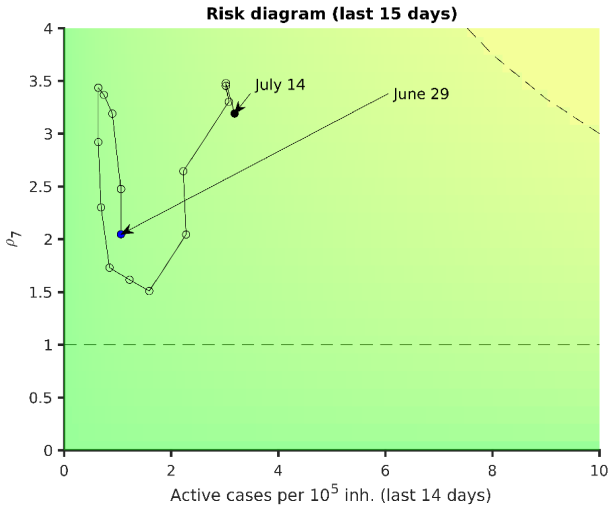




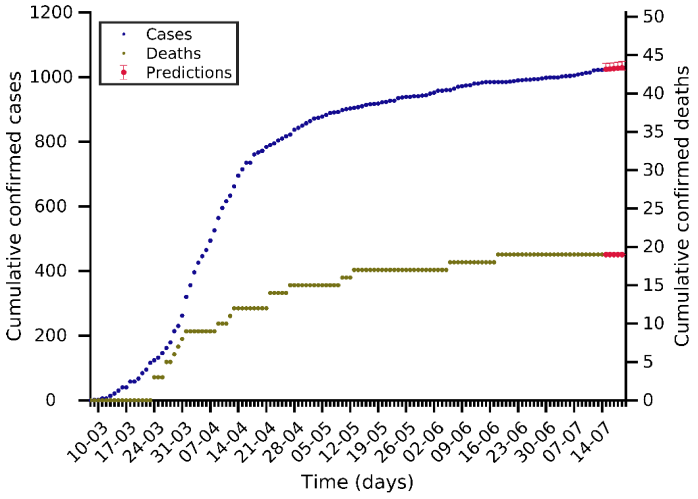


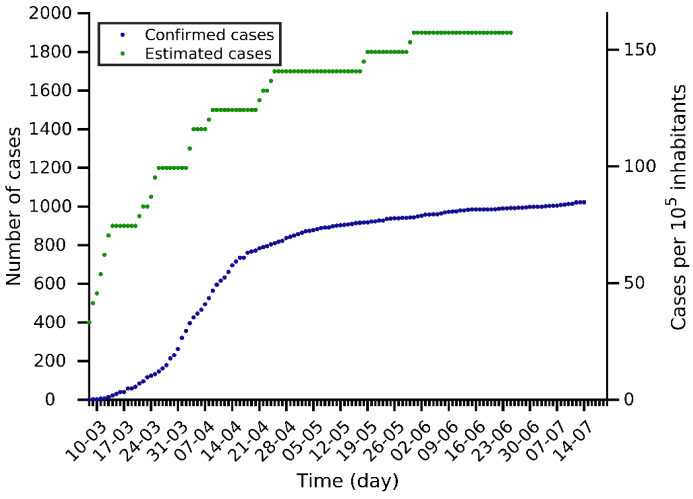


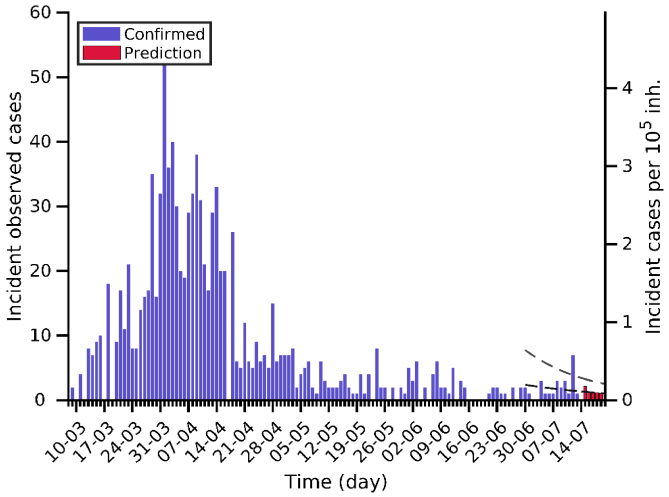


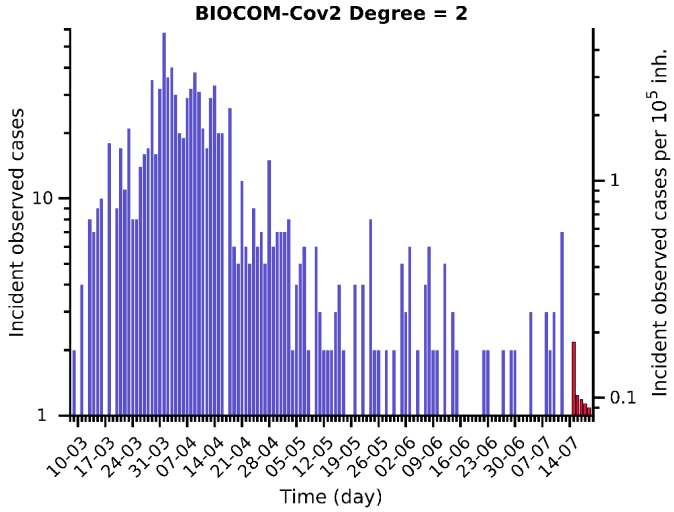


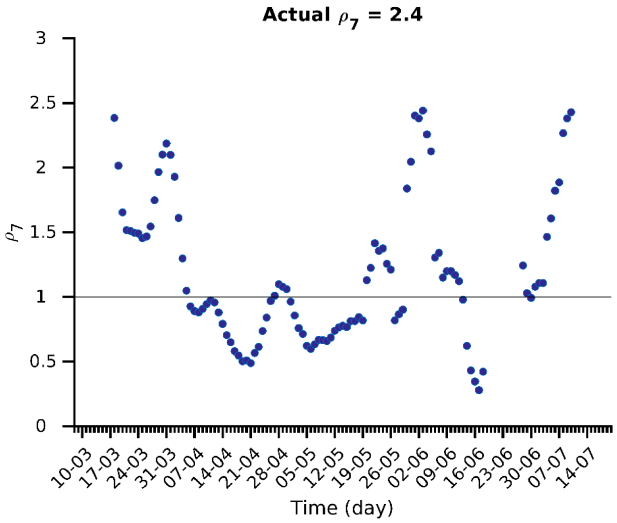
Cyprus 14-07-2020. Pop: 1.2M. Cumulative incidence: 85/10^5

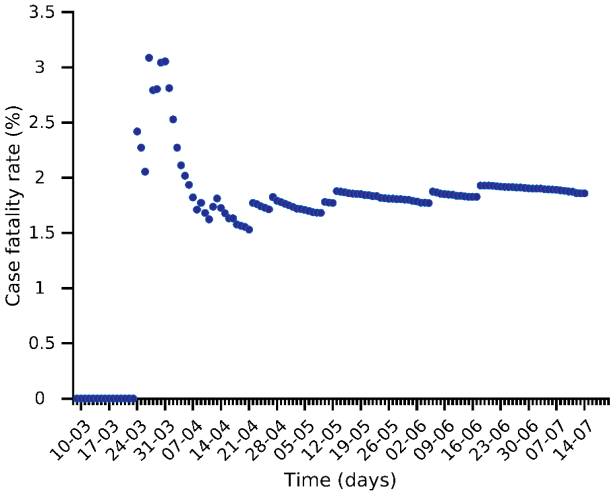


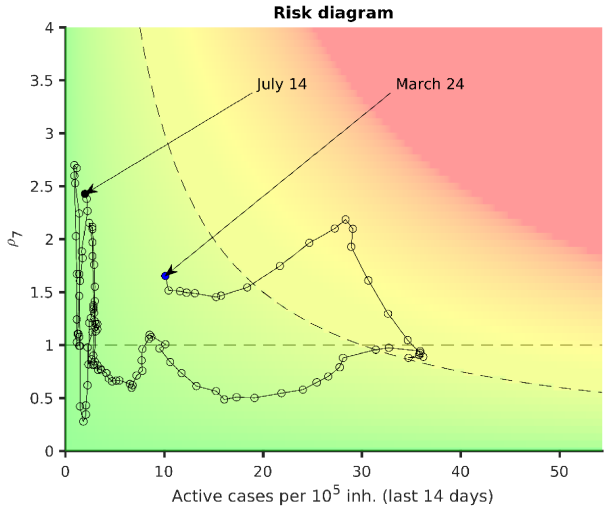


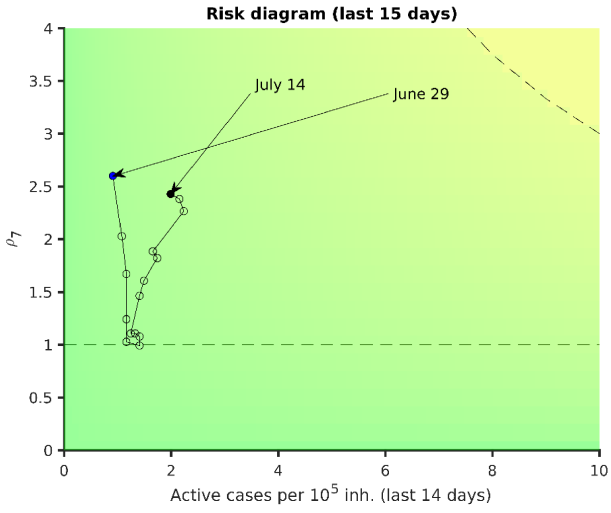




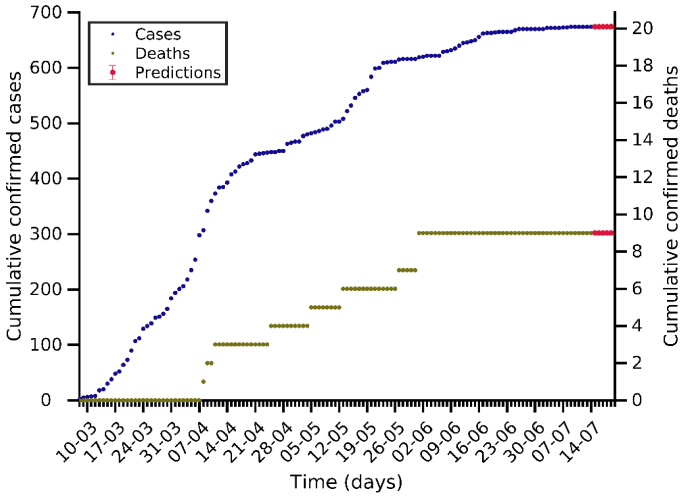


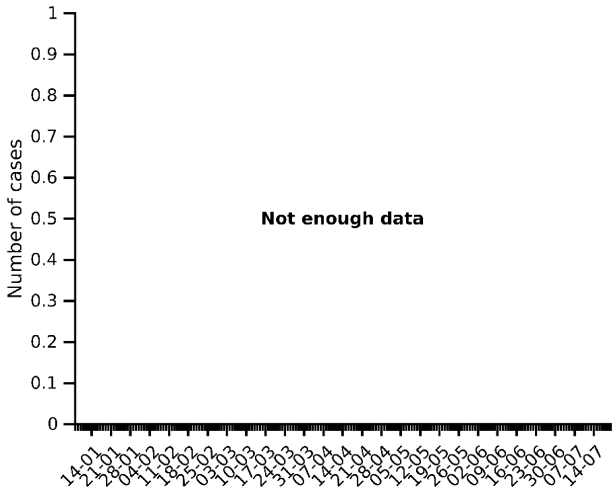


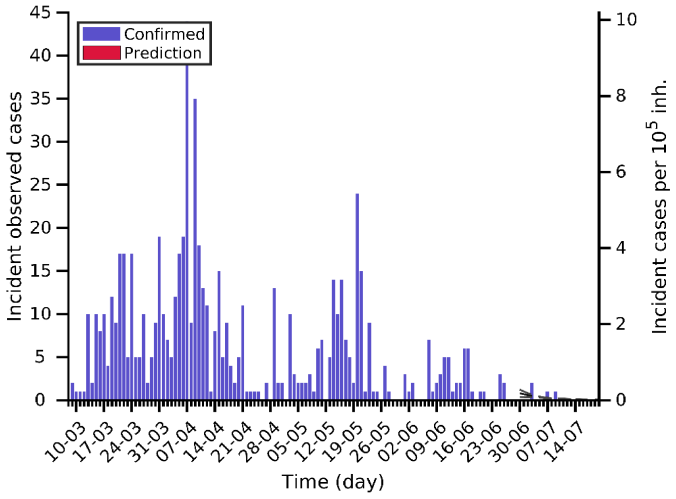


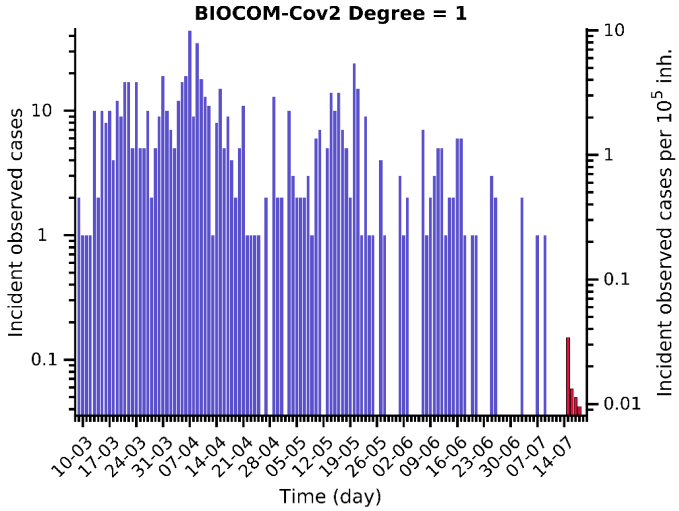


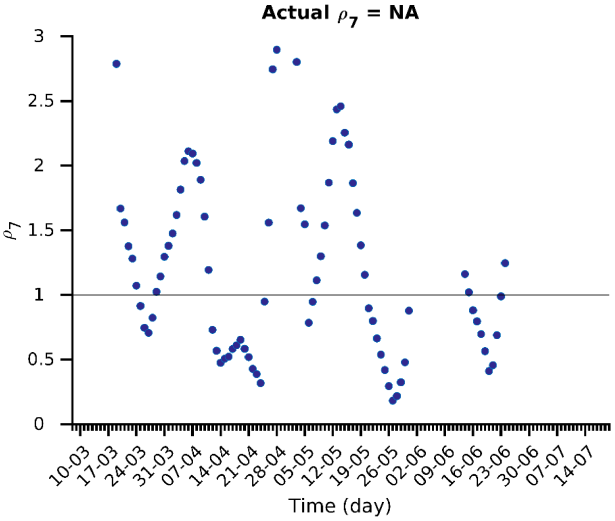
Malta 14-07-2020. Pop: 0.4M. Cumulative incidence: 153/10⁵

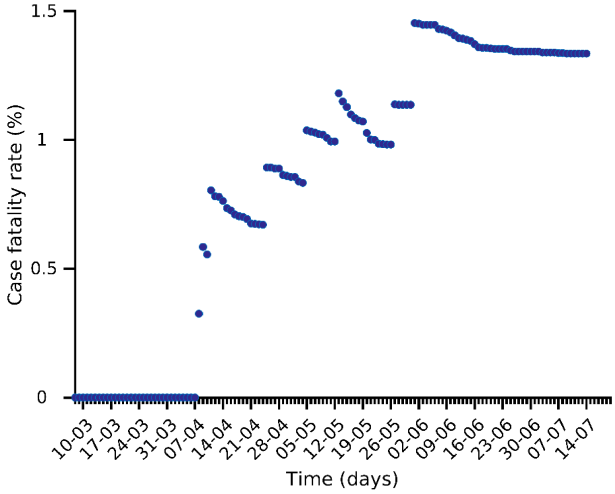


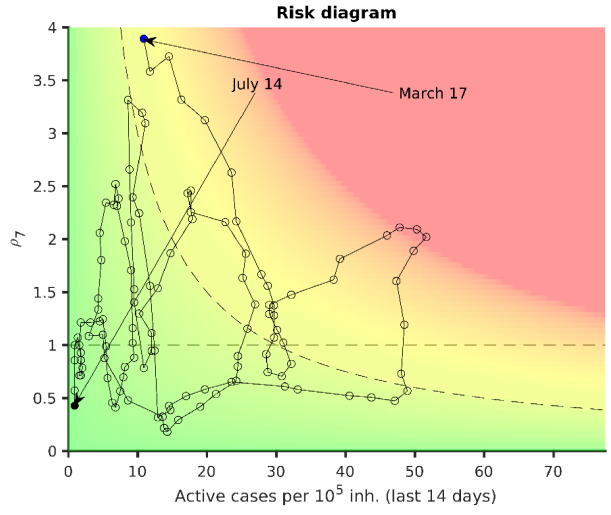


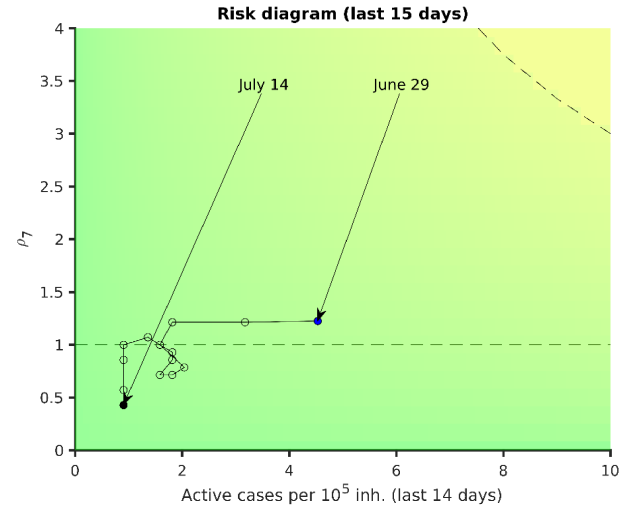








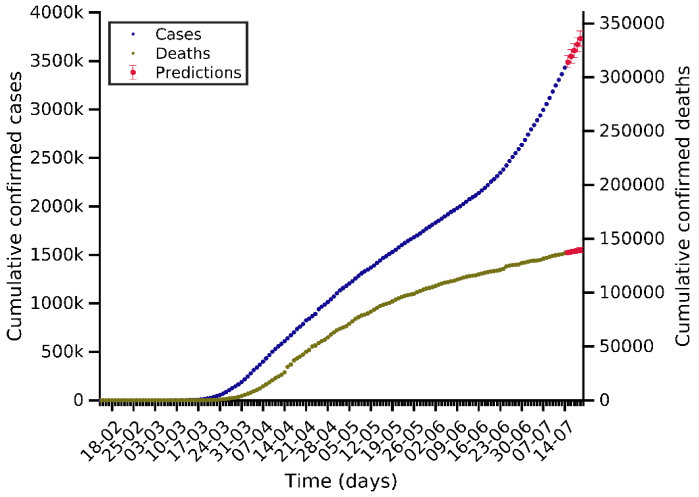


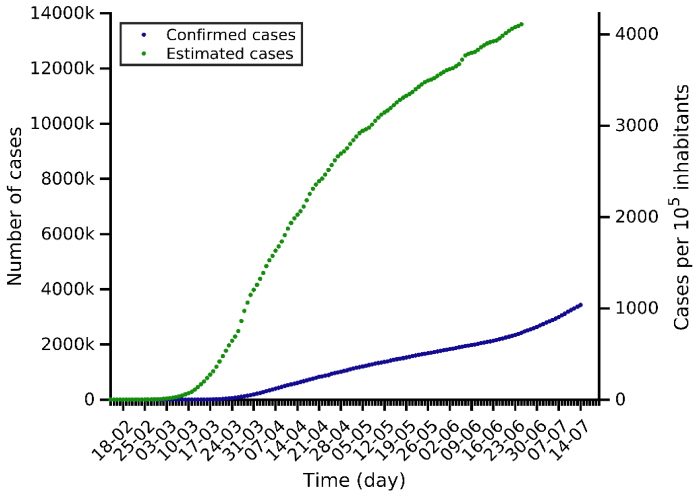


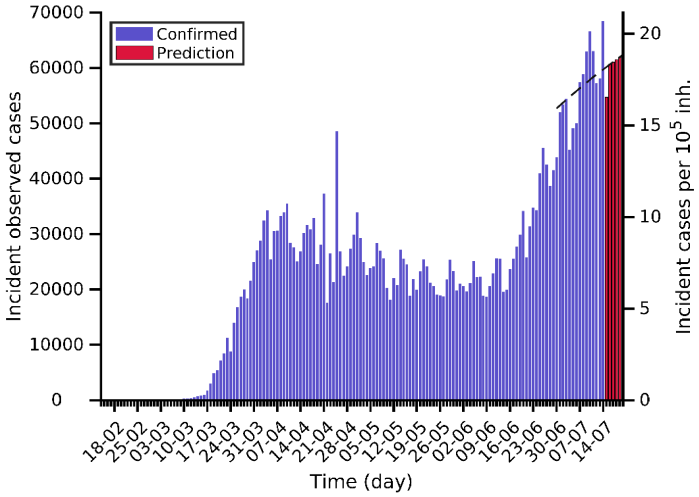
(2) Analysis and prediction of COVID-19 for other countries

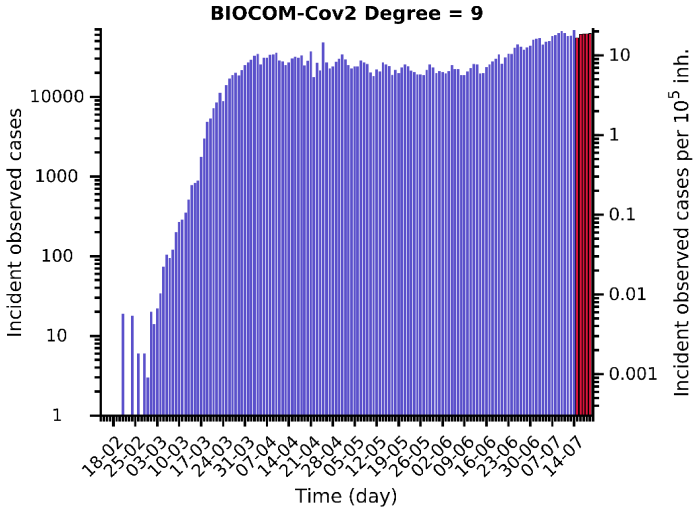
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

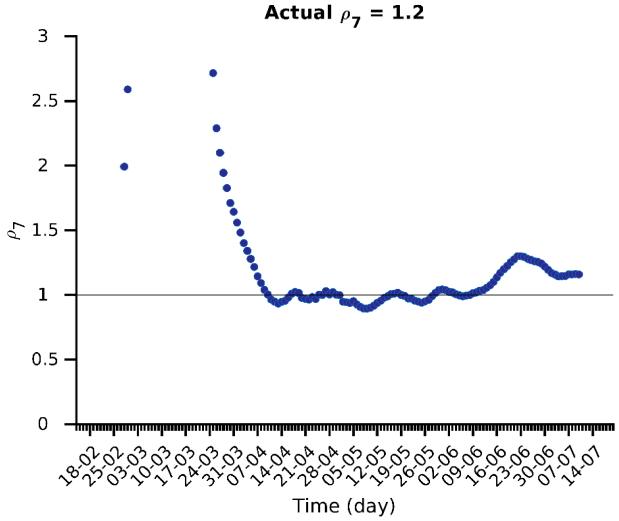
USA 14-07-2020. Pop: 331.0M. Cumulative incidence: 1037/10⁵

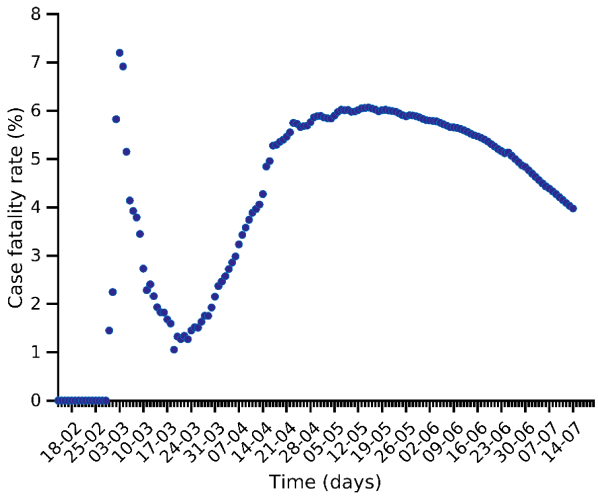


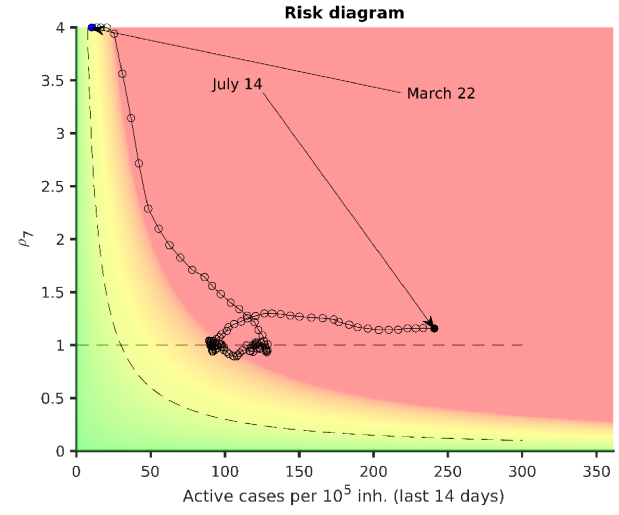


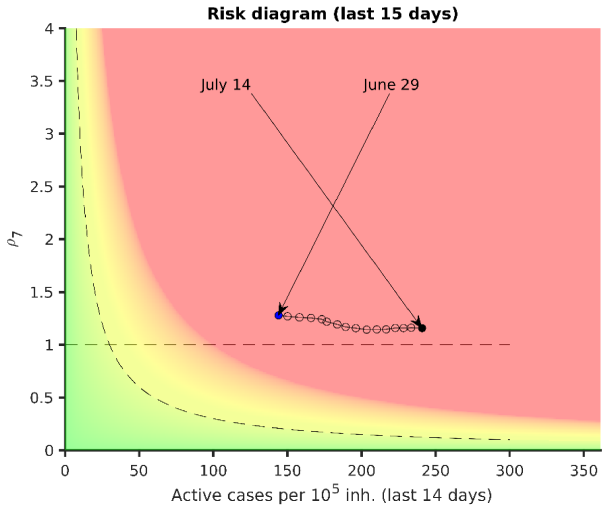




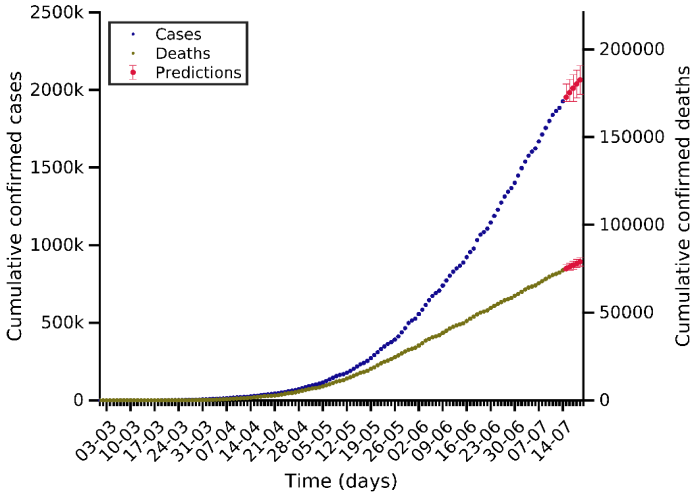


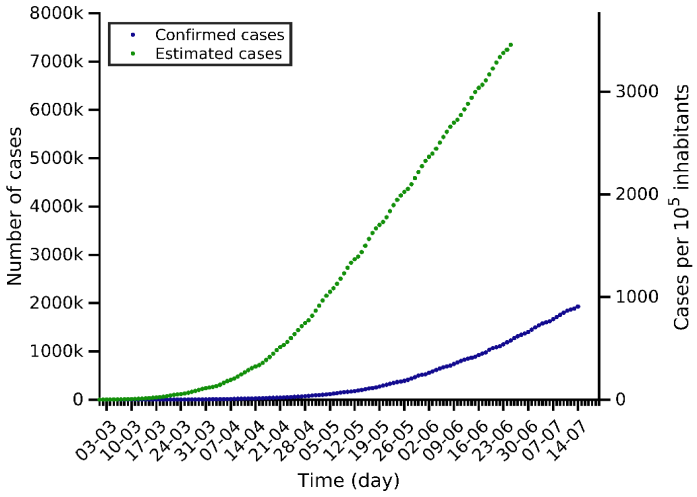


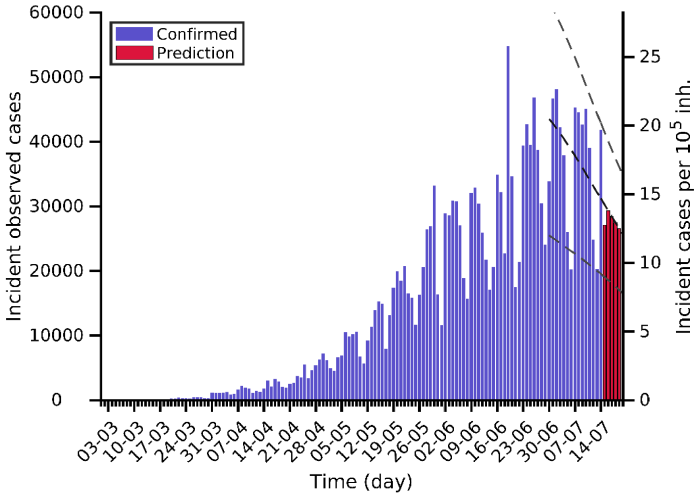


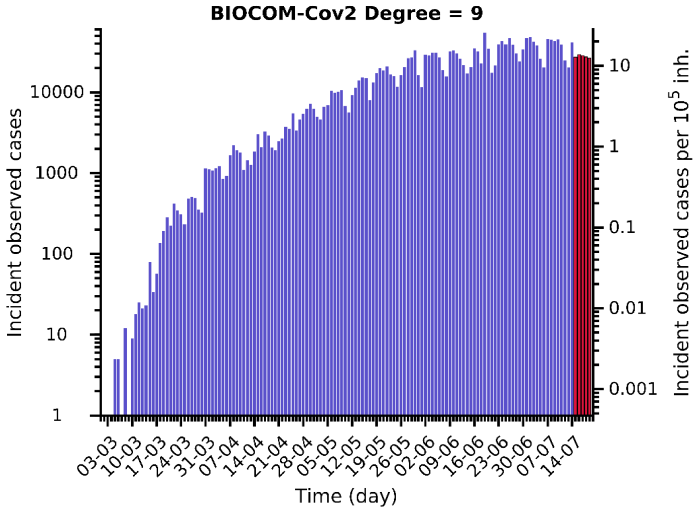


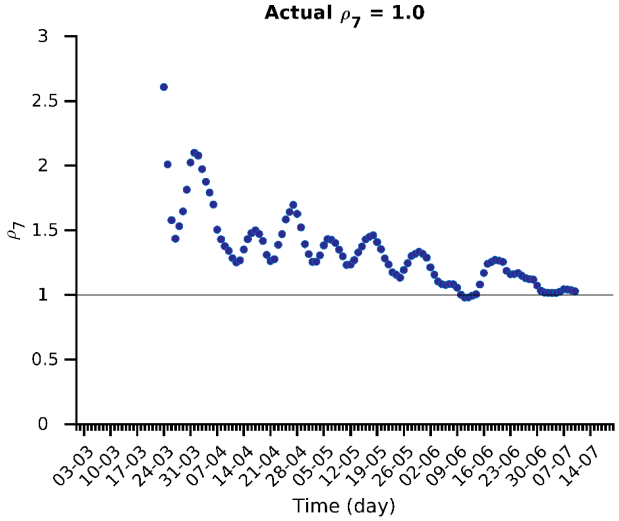
Brazil 14-07-2020. Pop: 212.6M. Cumulative incidence: 906/10⁵

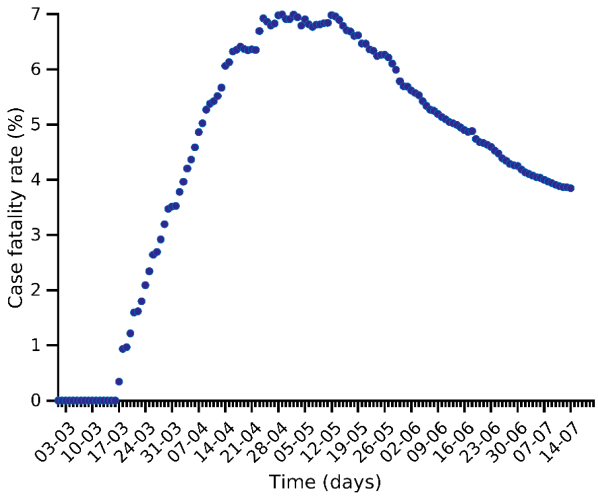


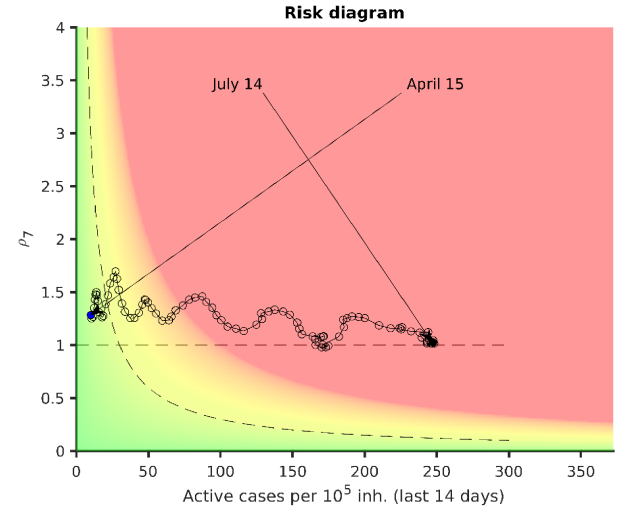


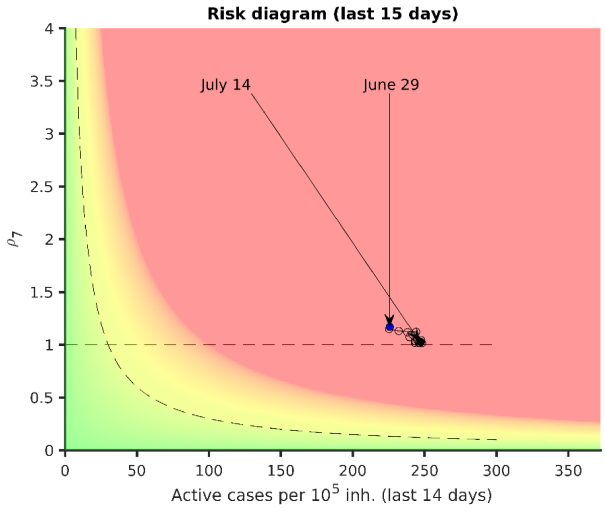




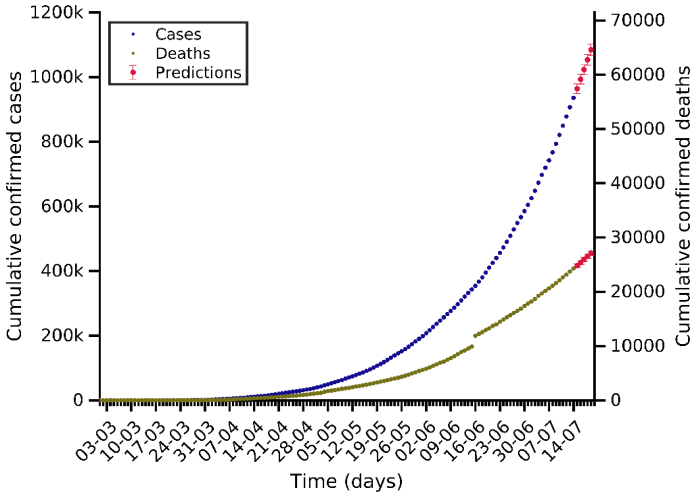


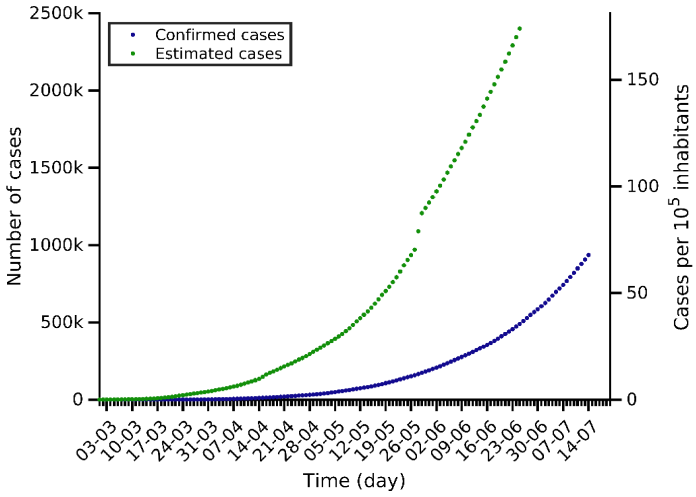


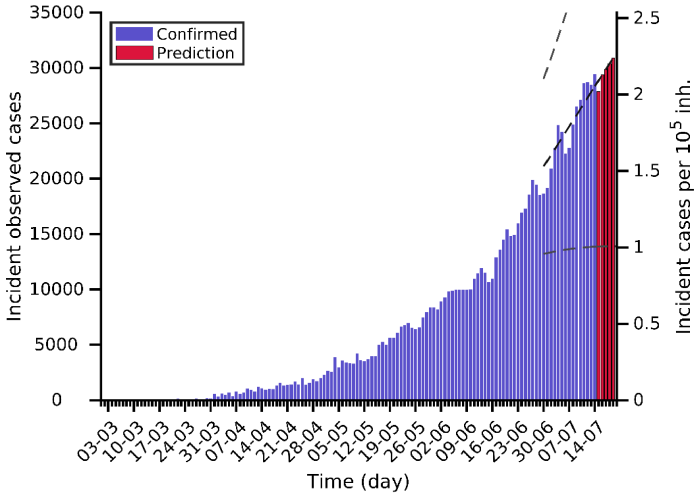


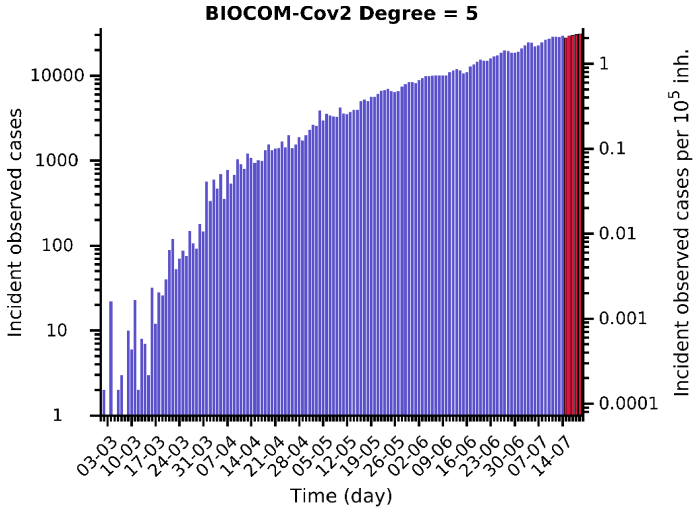


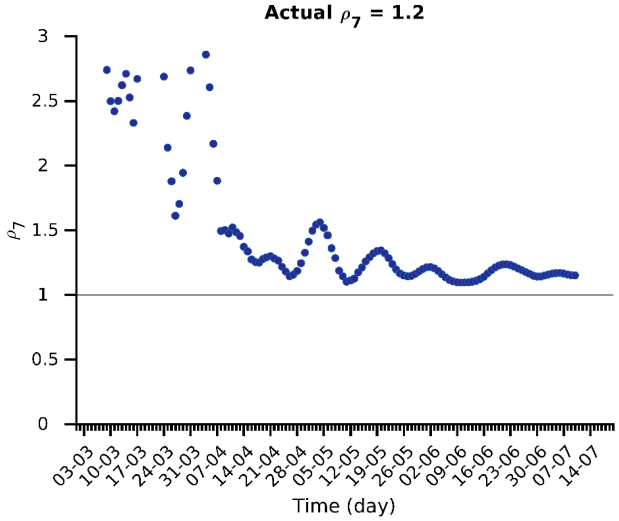
India 14-07-2020. Pop: 1380.0M. Cumulative incidence: 68/10⁵

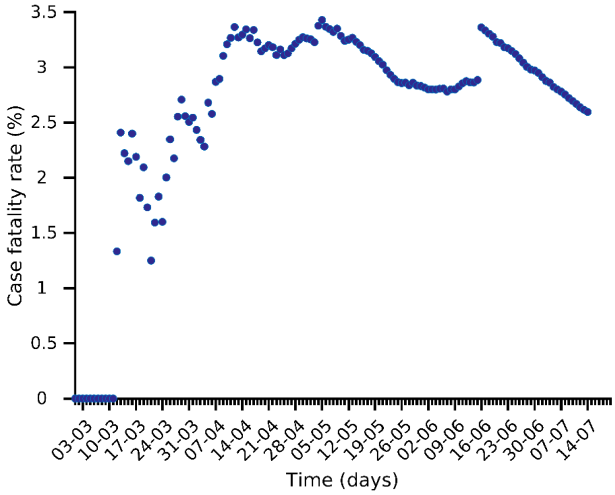


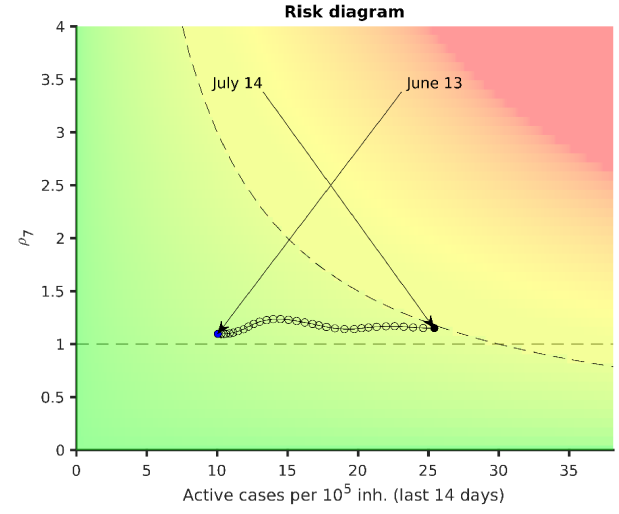


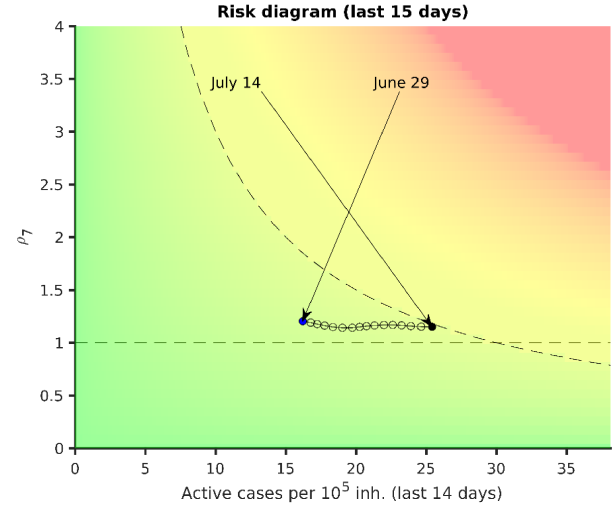




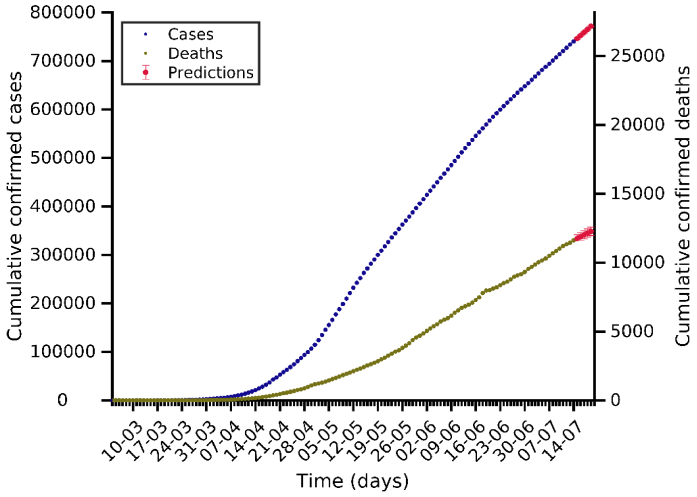


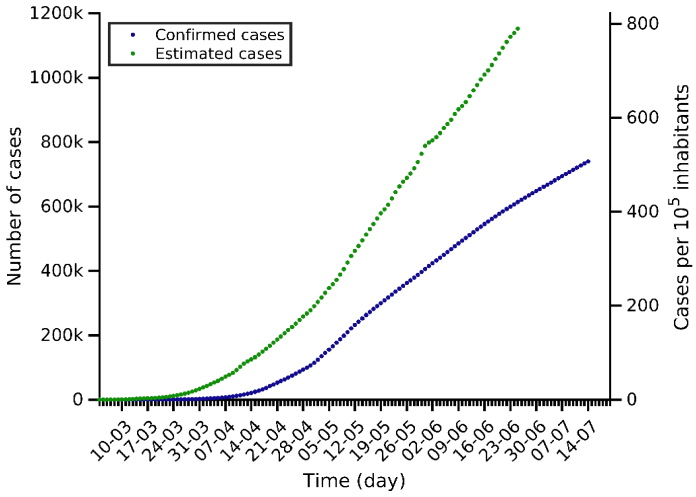


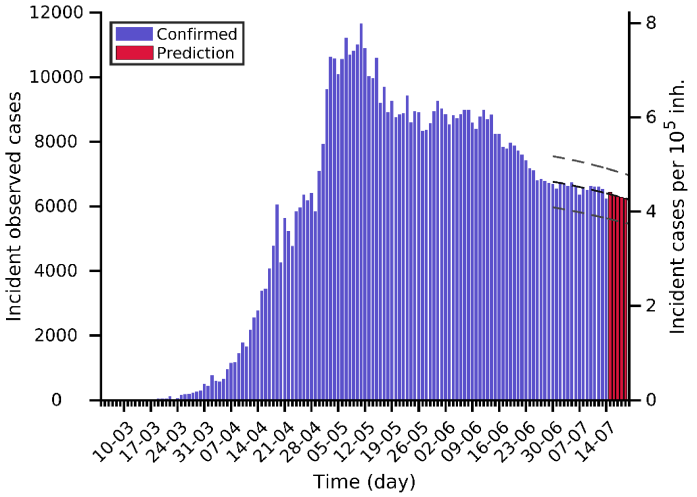


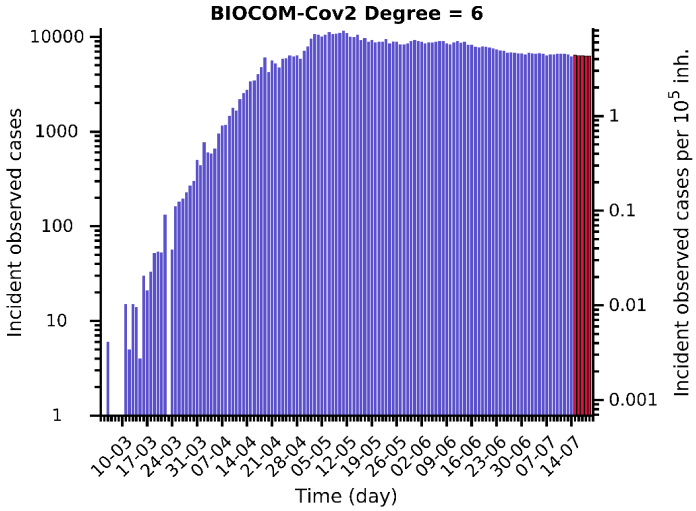


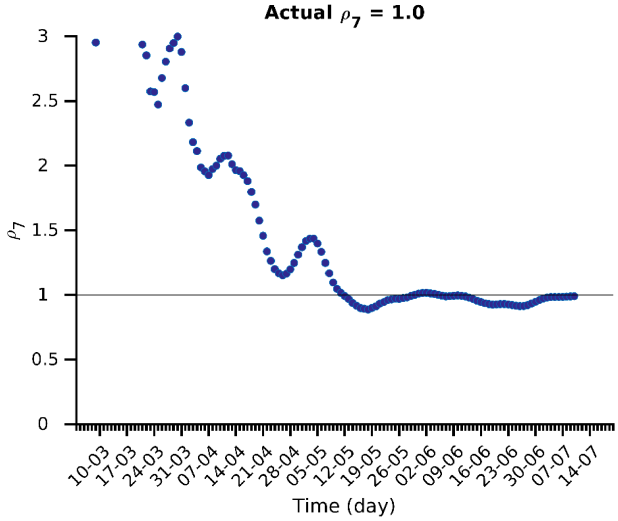
Russia 14-07-2020. Pop: 145.9M. Cumulative incidence: 507/10⁵

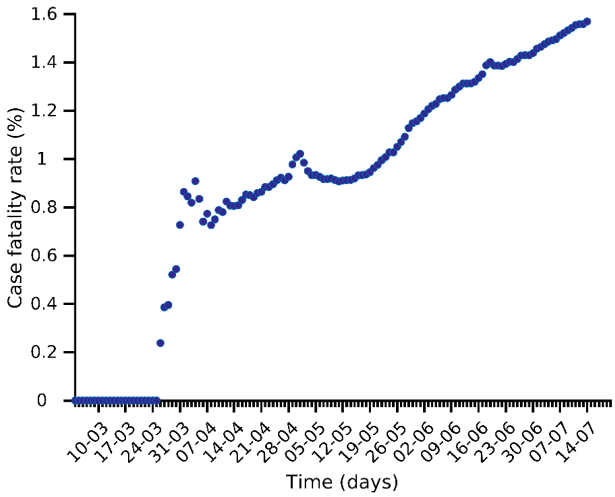


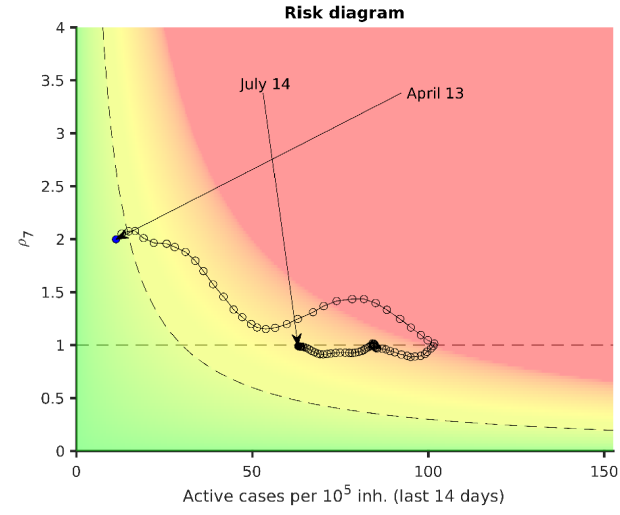


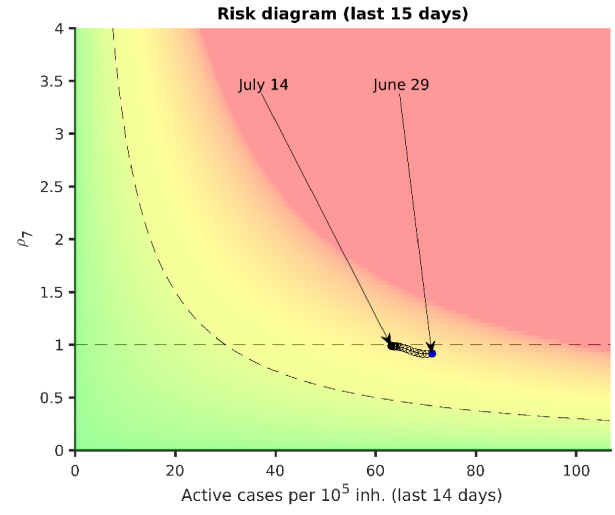




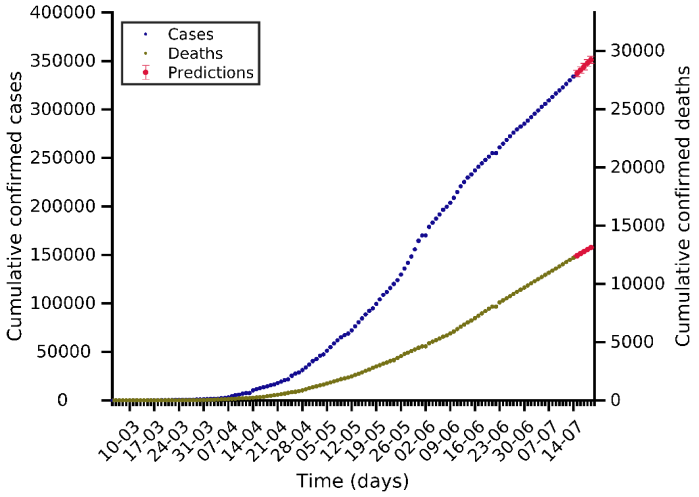


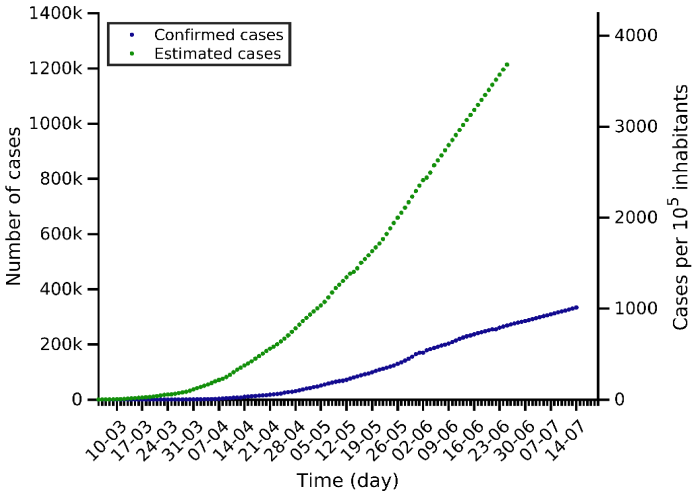


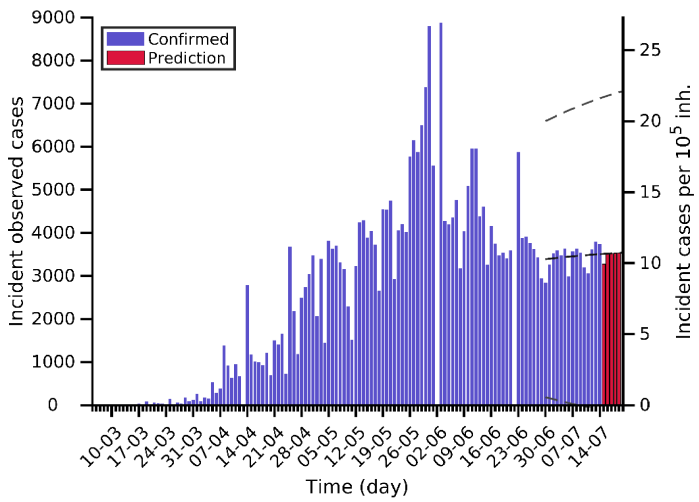


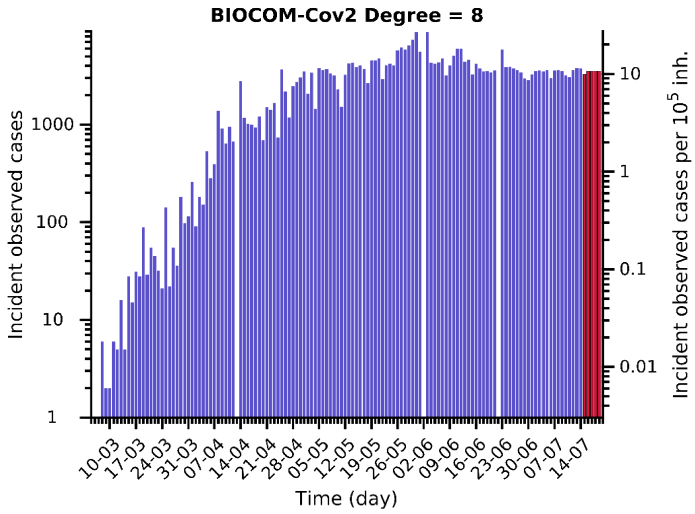


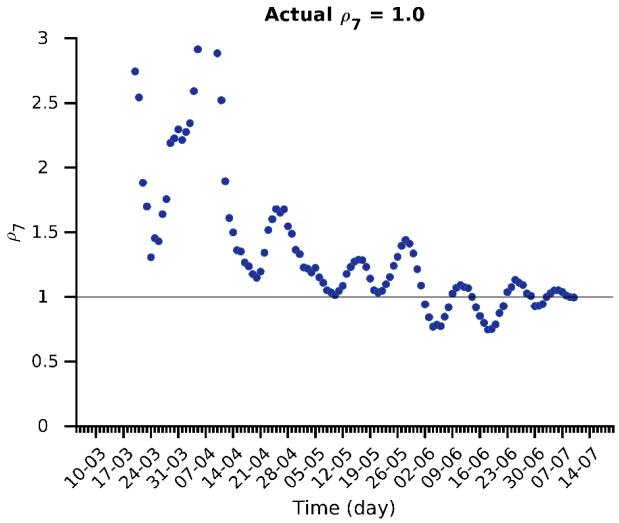
Peru 14-07-2020. Pop: 33.0M. Cumulative incidence: 1013/10⁵

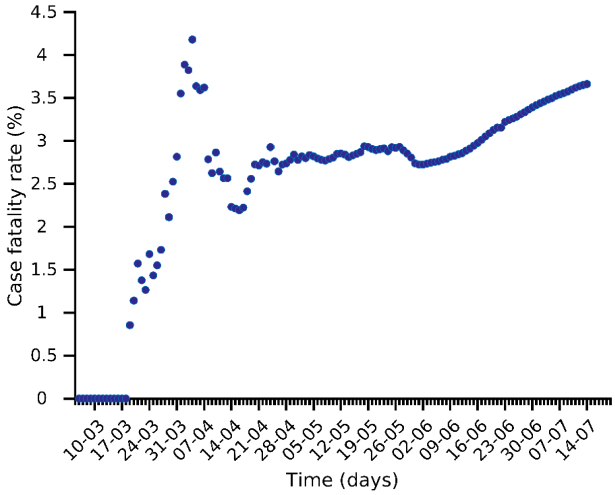


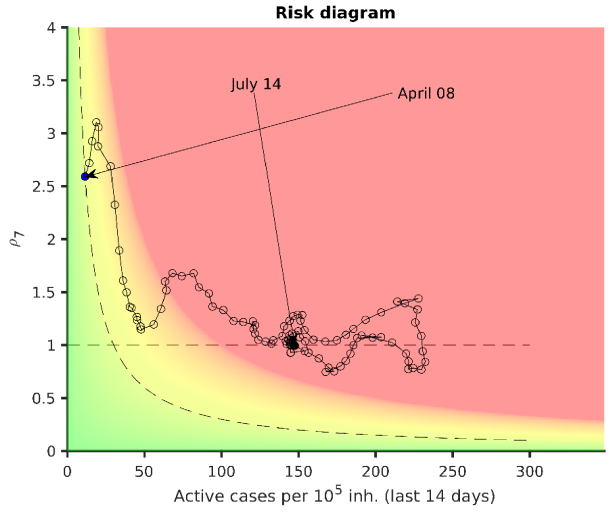


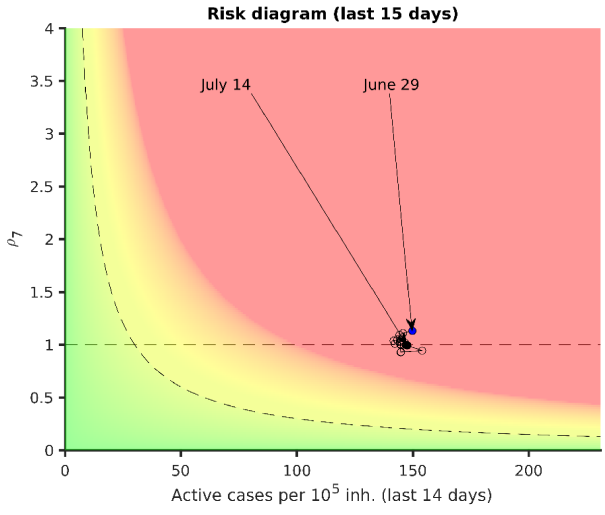




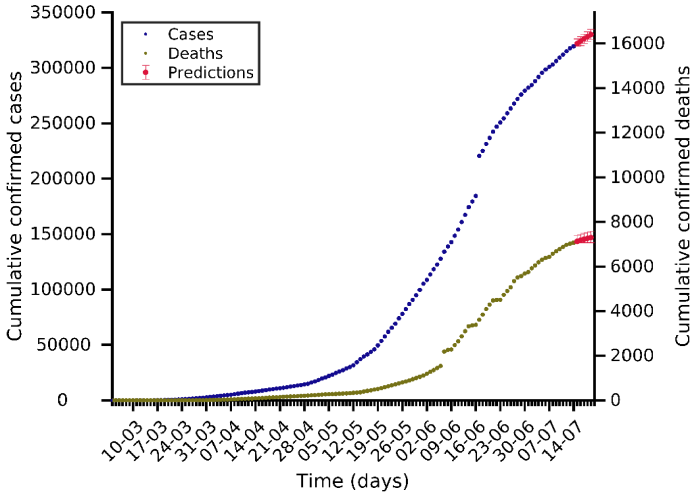


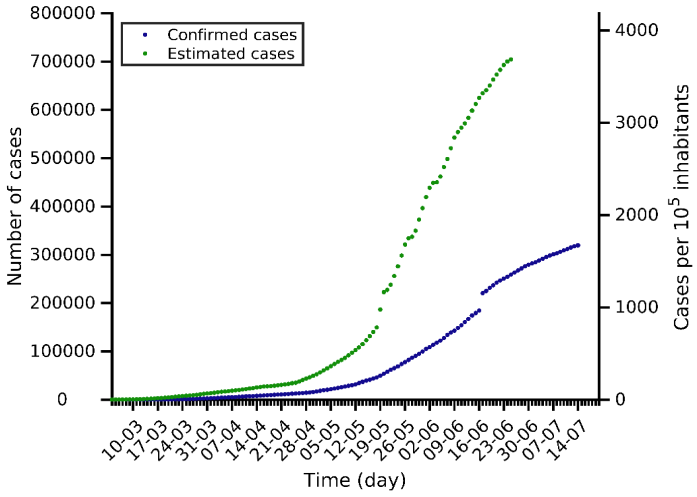


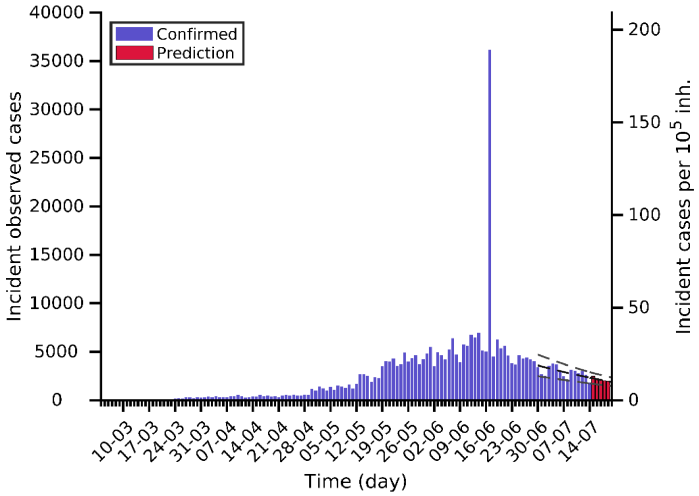


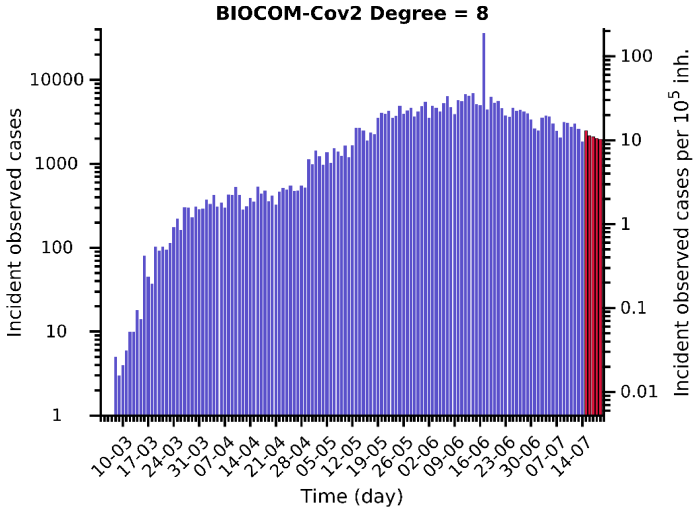


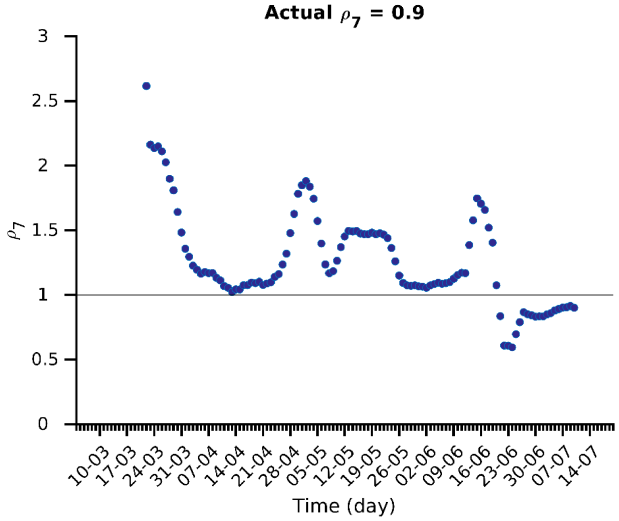
Chile 14-07-2020. Pop: 19.1M. Cumulative incidence: 1671/10^5

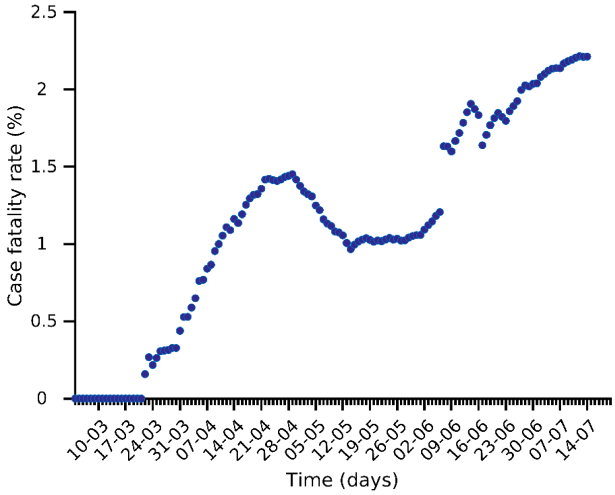


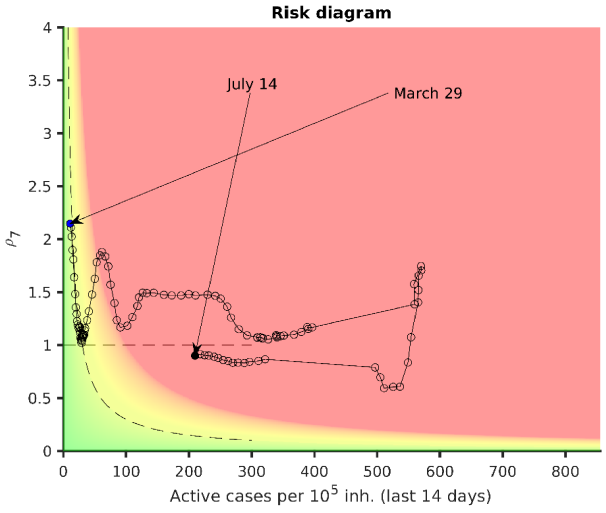


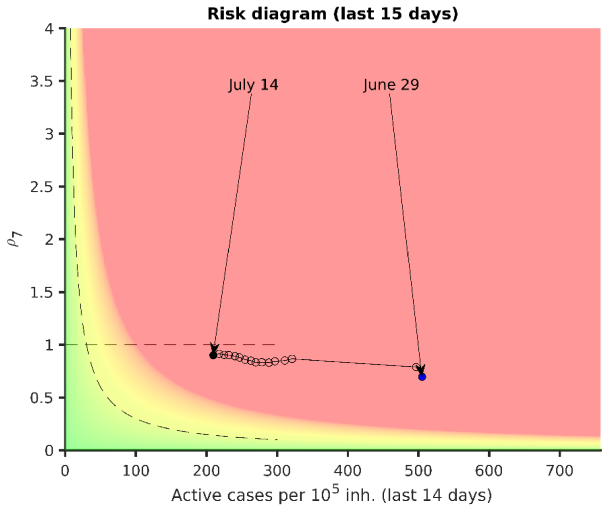




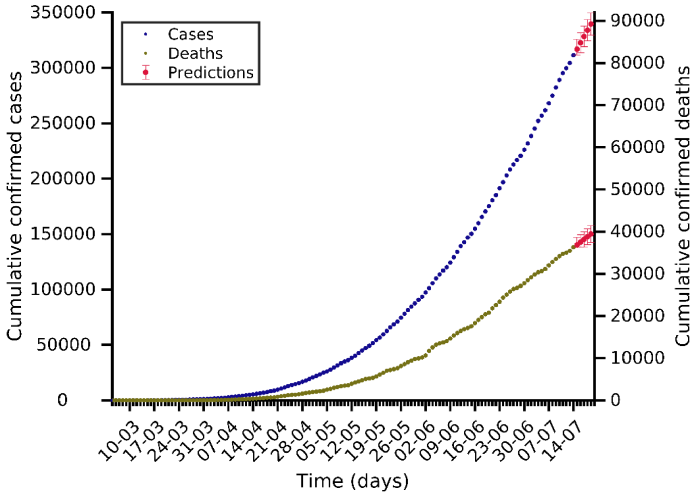


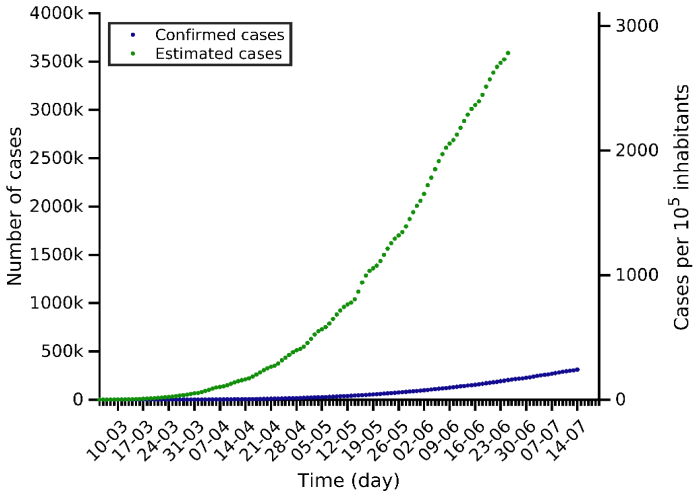


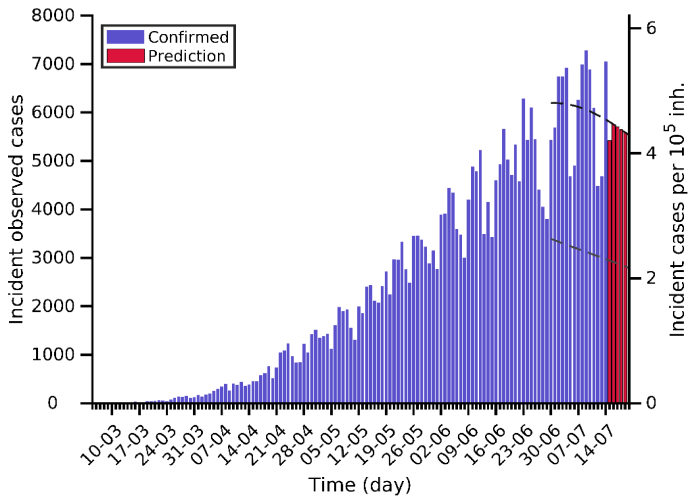


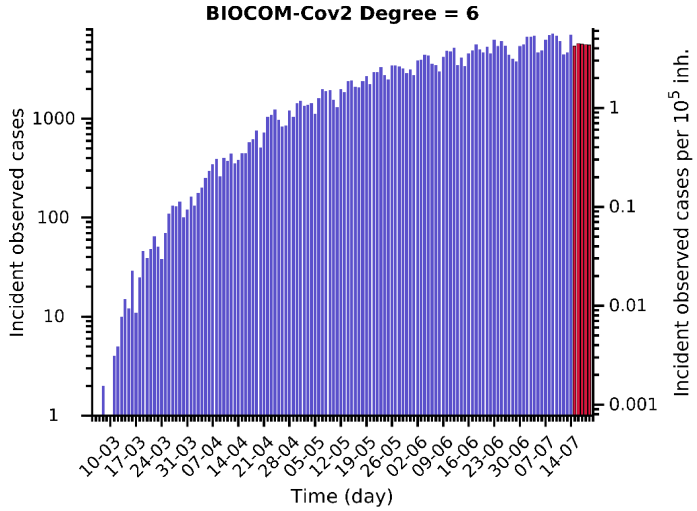


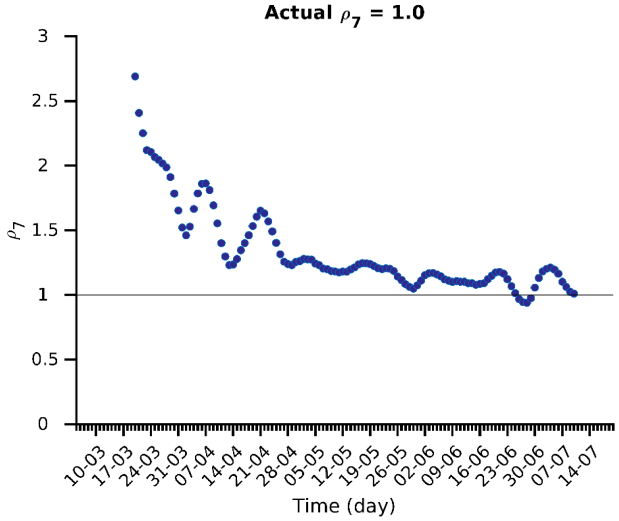
Mexico 14-07-2020. Pop: 128.9M. Cumulative incidence: 242/10⁵

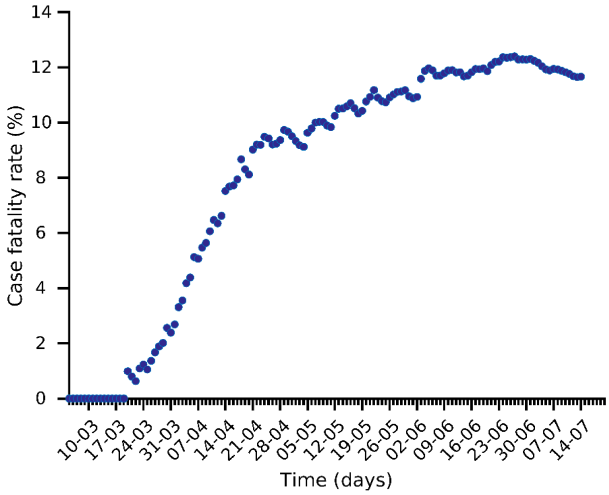


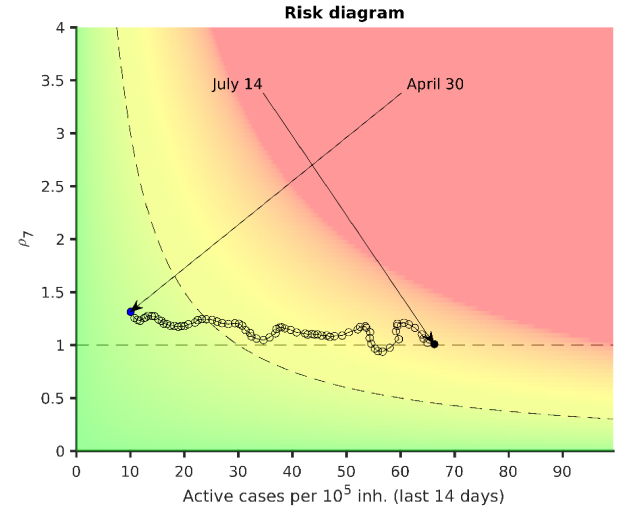


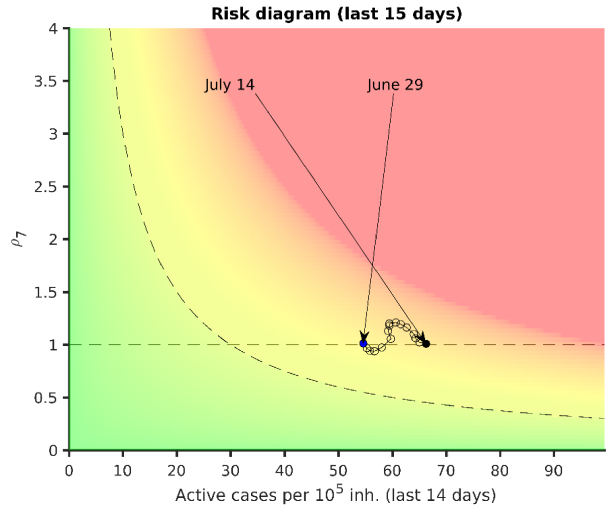




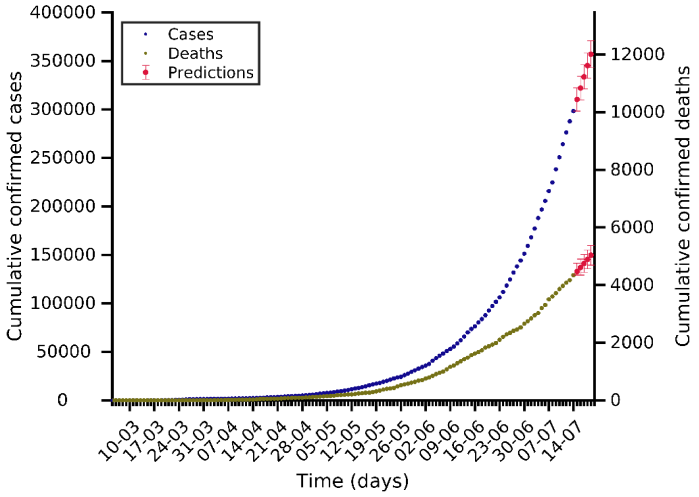


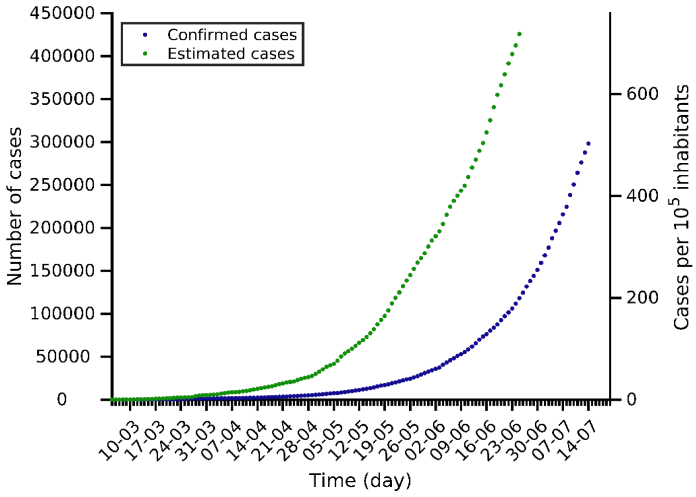


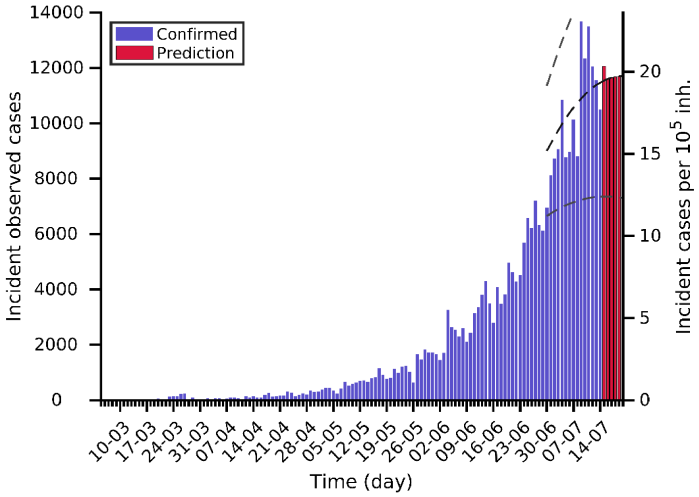


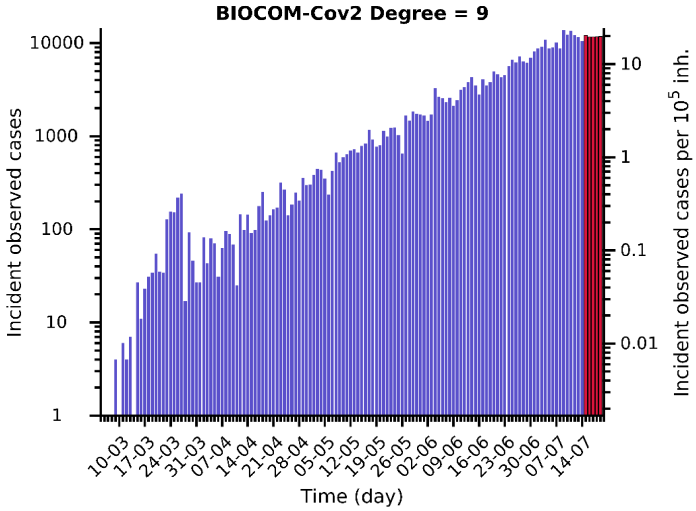


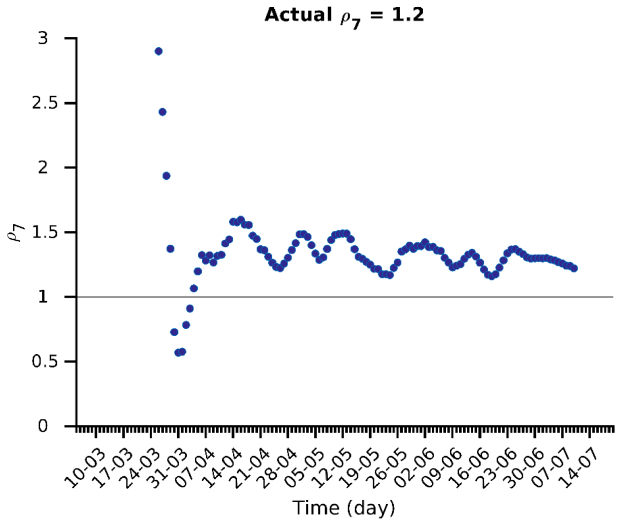
South Africa 14-07-2020. Pop: 59.3M. Cumulative incidence: 503/10⁵

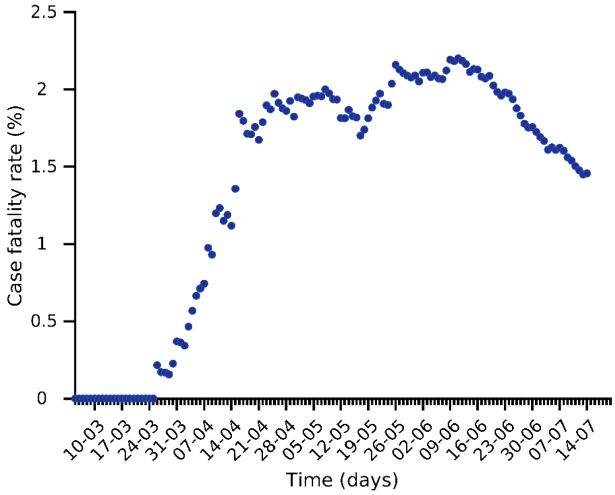


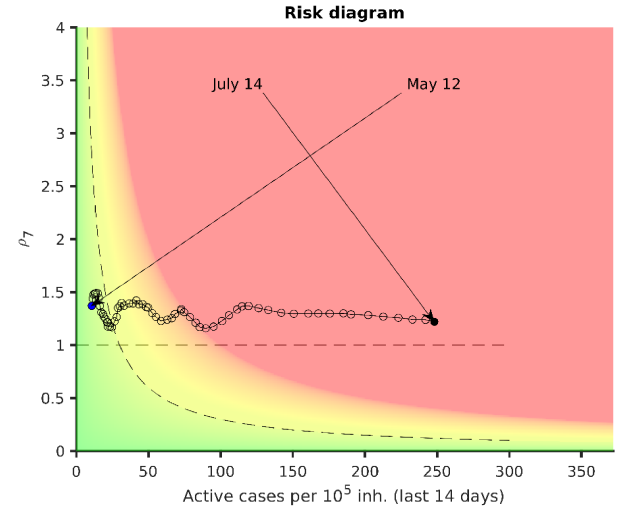


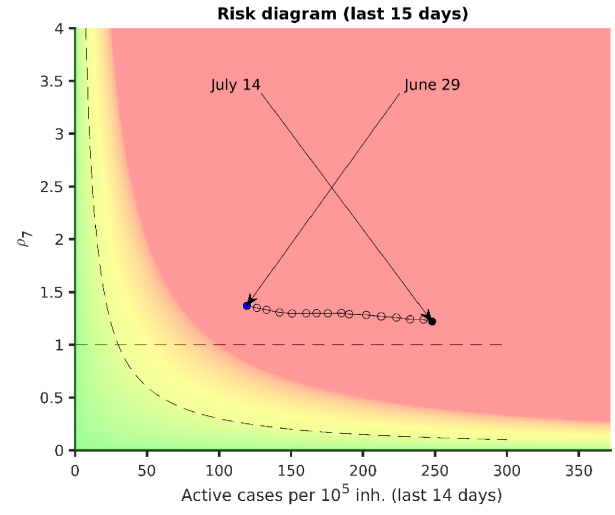




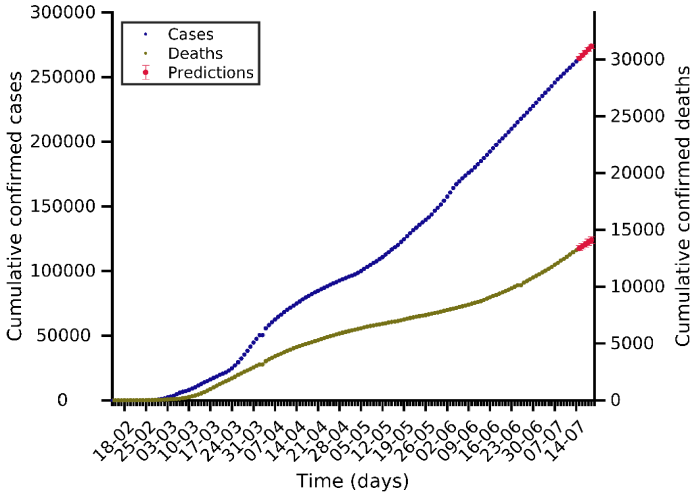


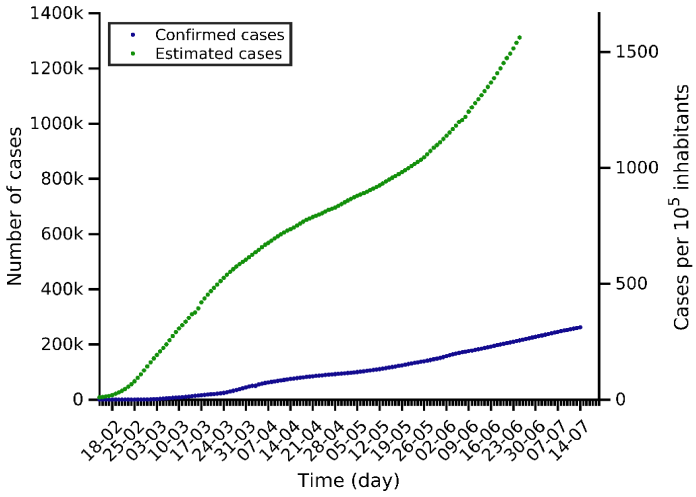


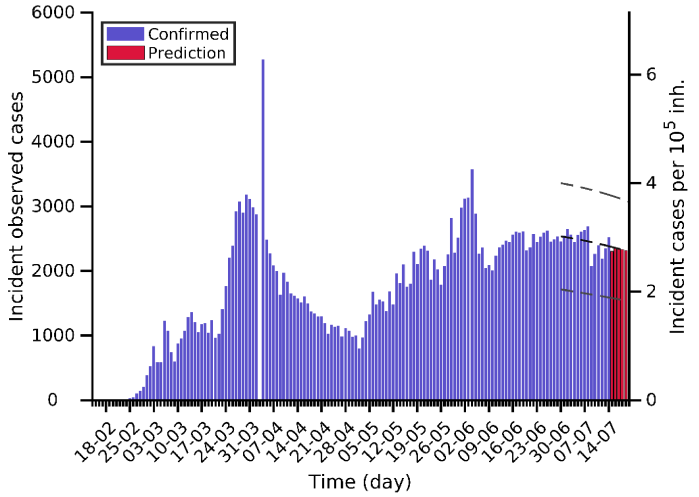


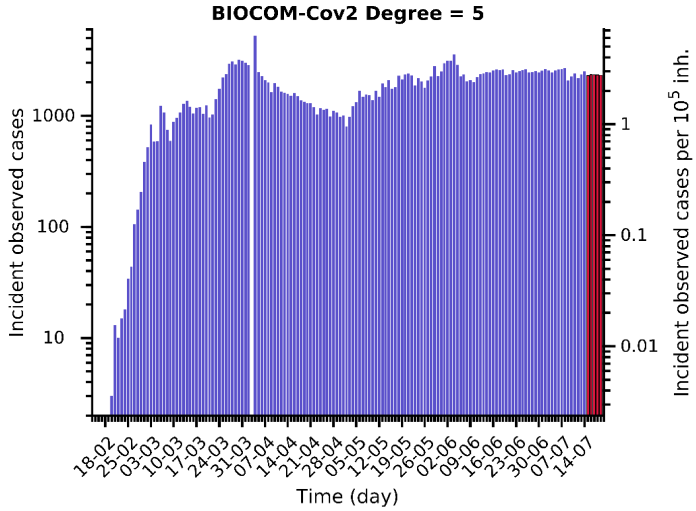


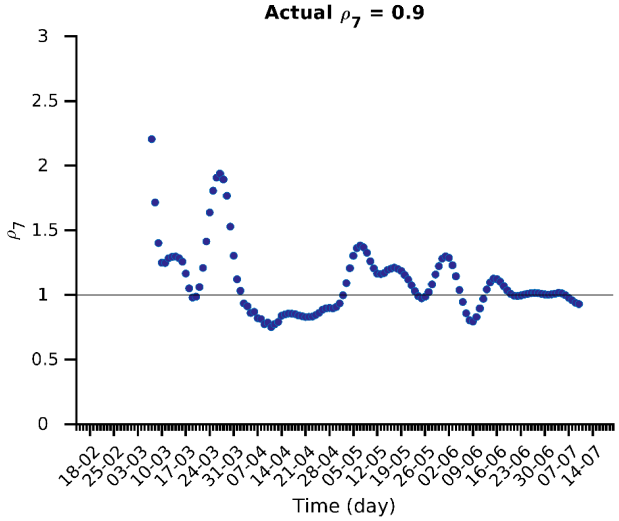
Iran 14-07-2020. Pop: 84.0M. Cumulative incidence: 312/10⁵

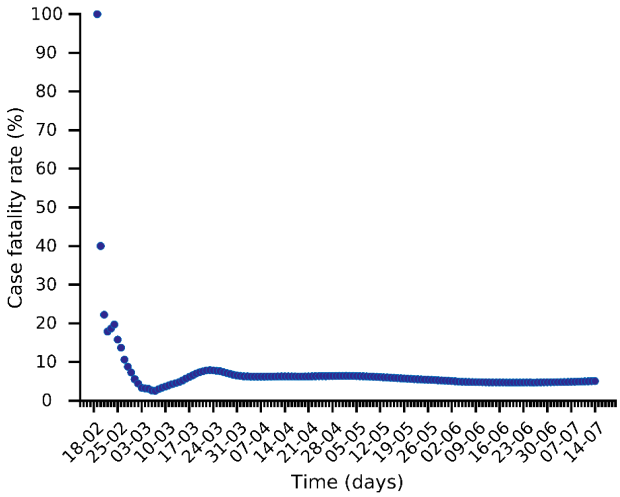


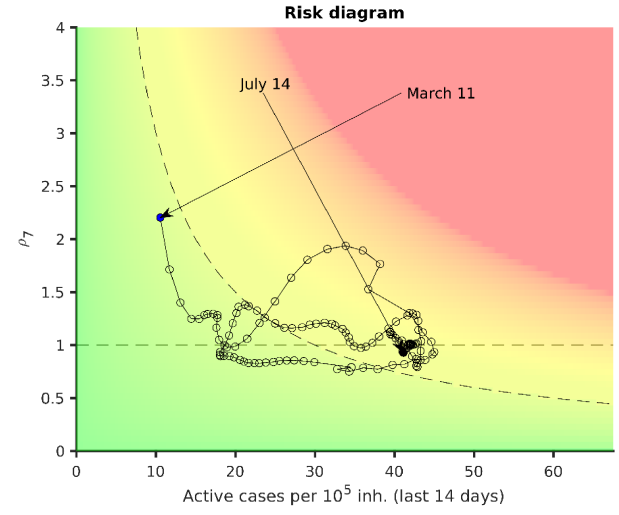


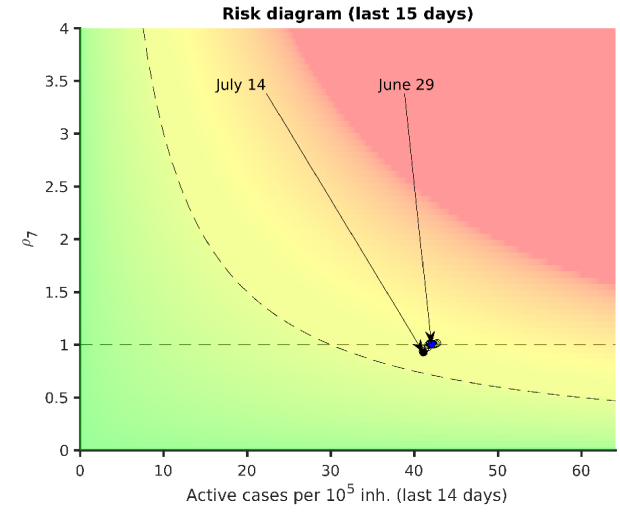




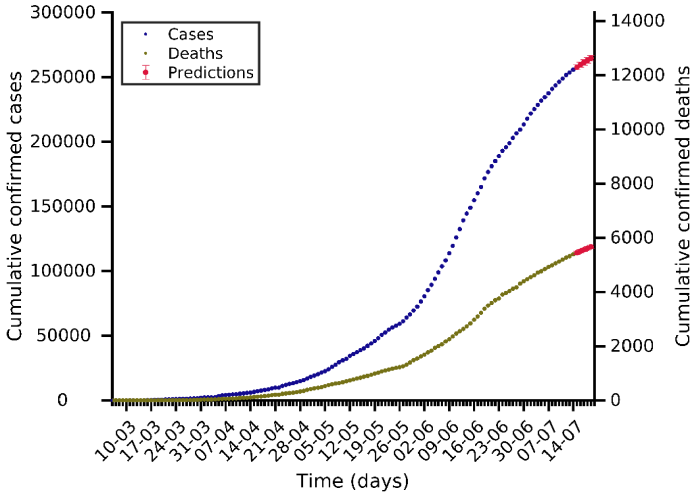


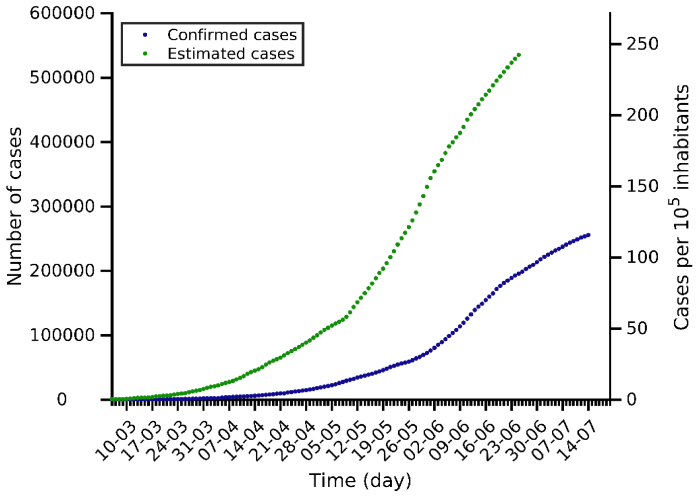


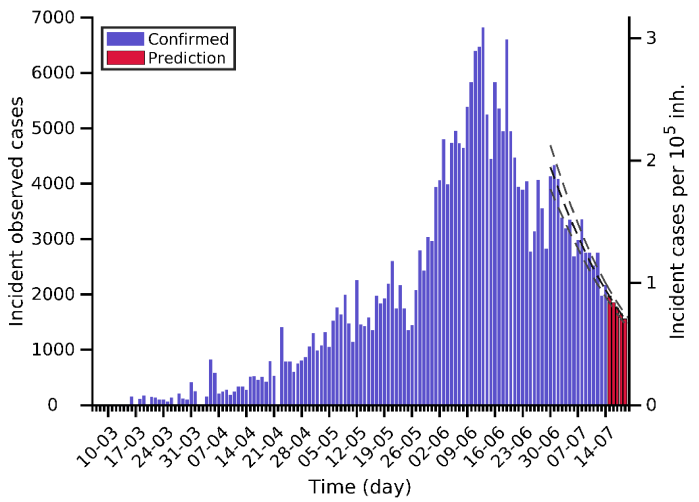


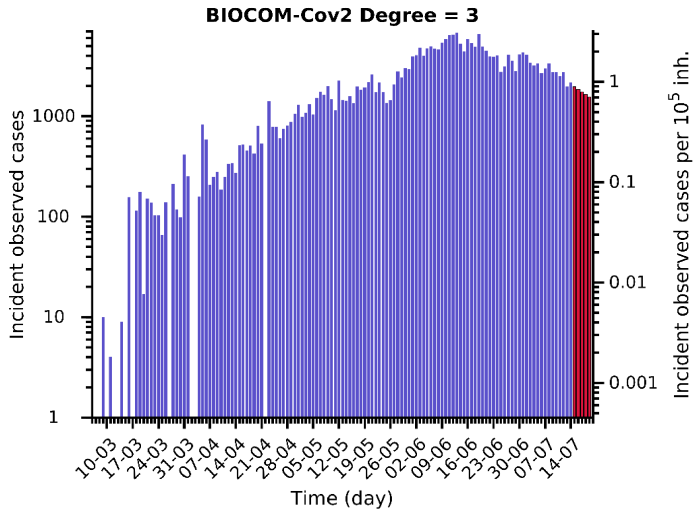


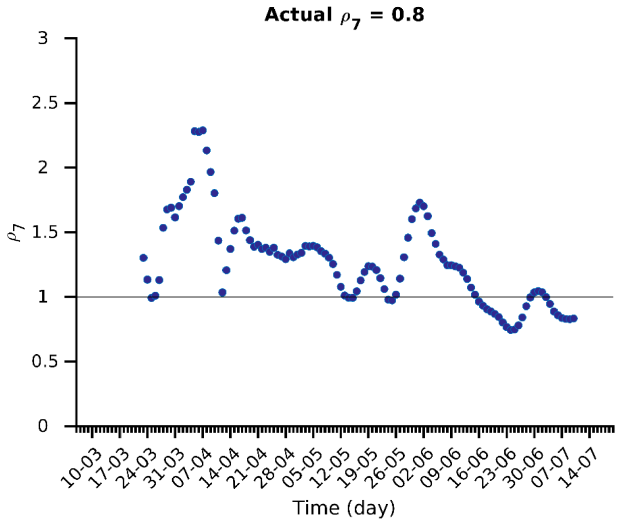
Pakistan 14-07-2020. Pop: 220.9M. Cumulative incidence: 116/10⁵

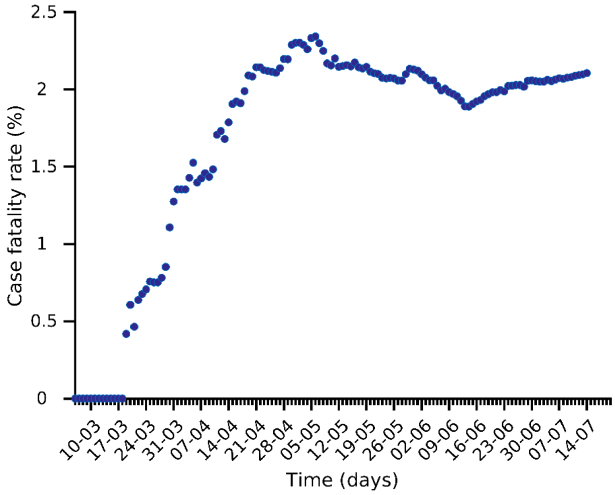


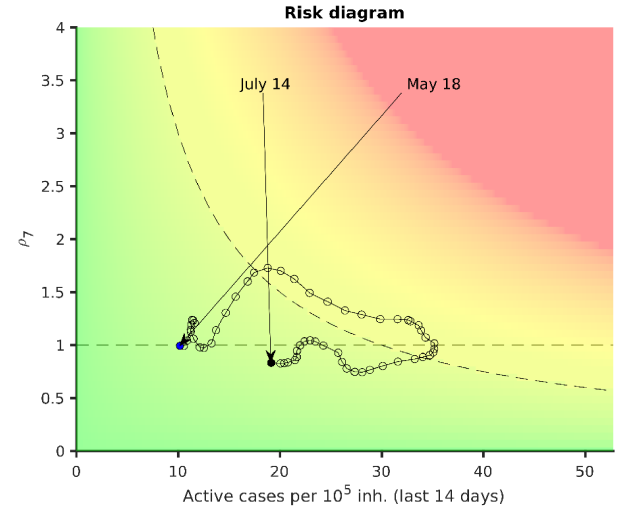


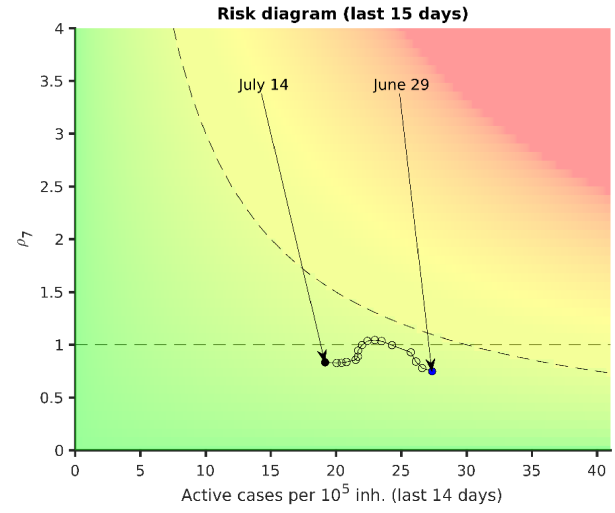




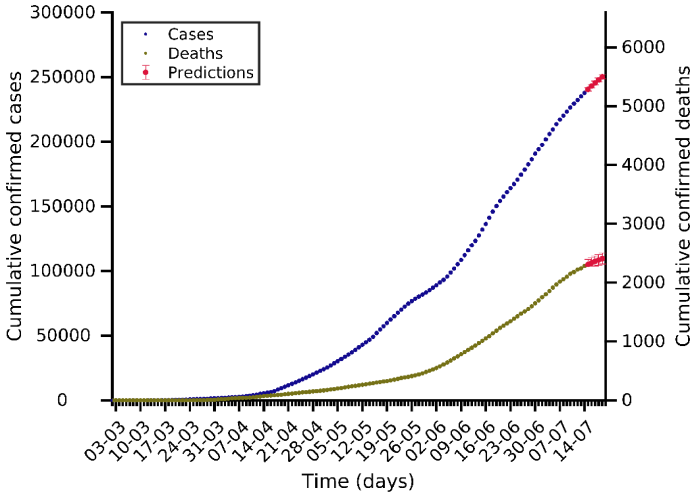


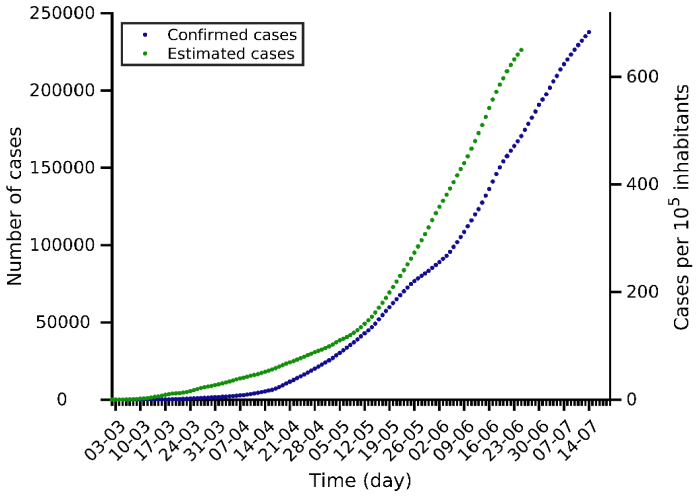


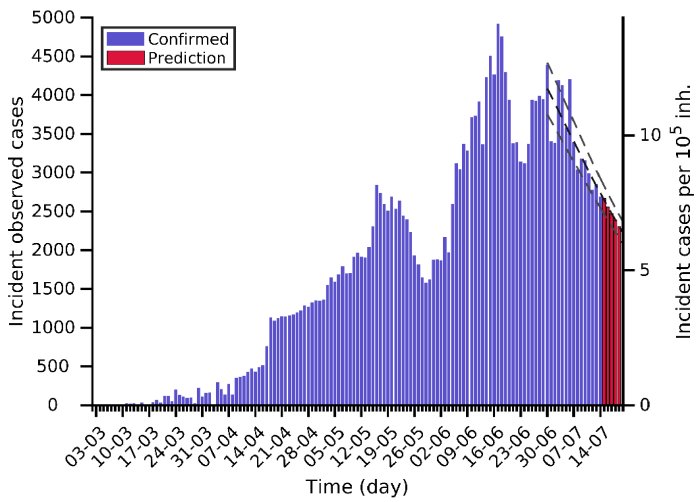


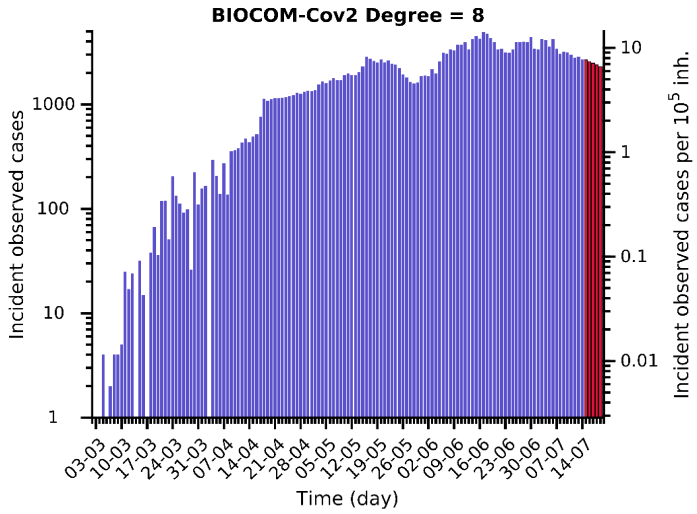


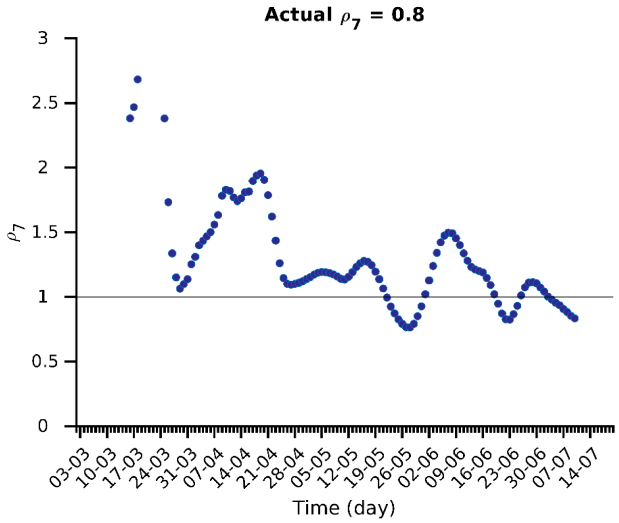
Saudi Arabia 14-07-2020. Pop: 34.8M. Cumulative incidence: 683/10⁵

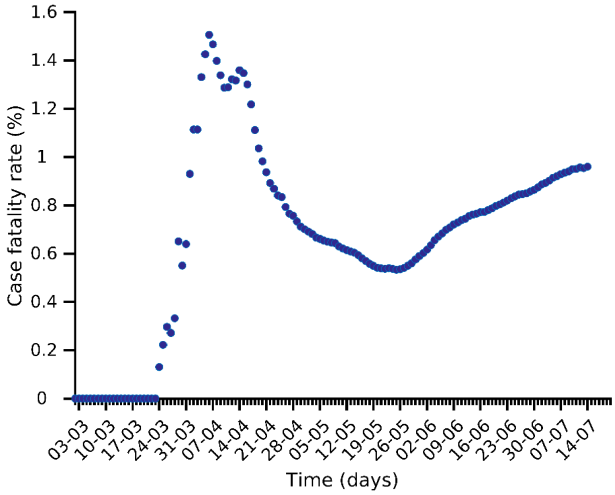


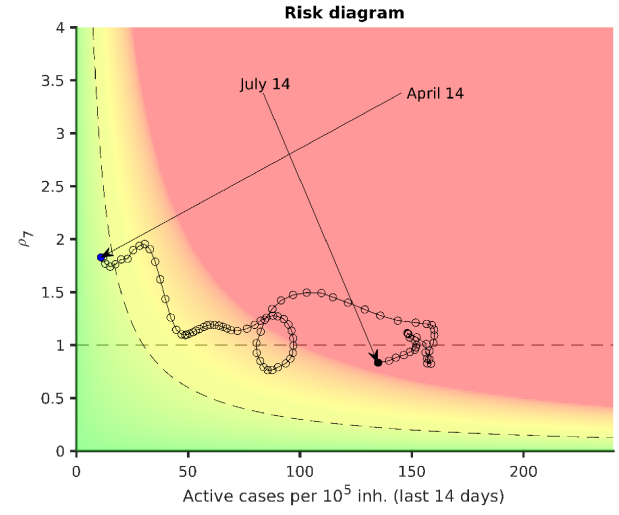


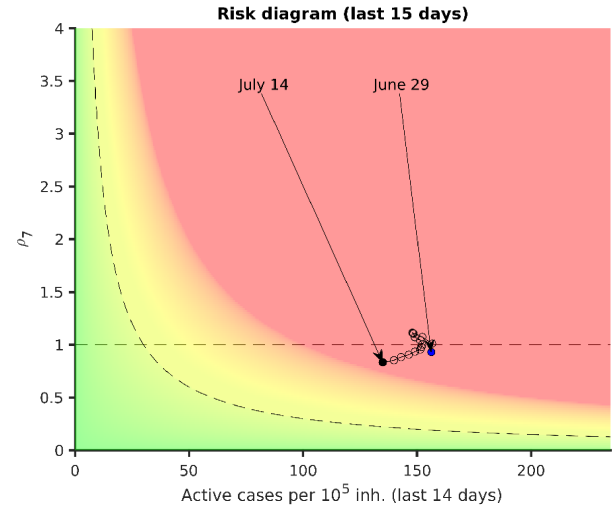




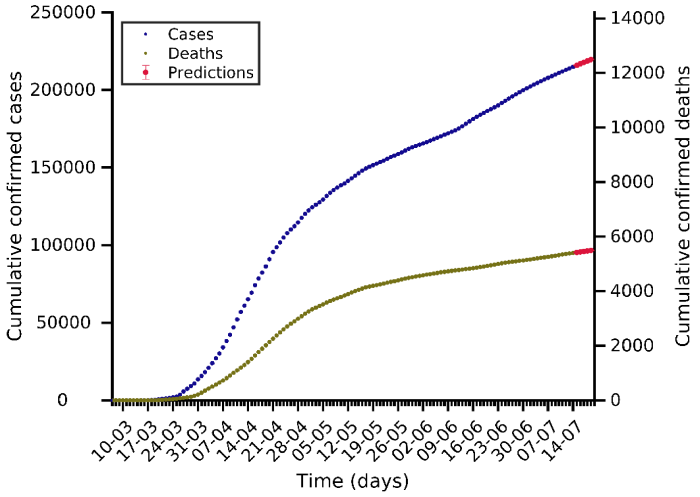


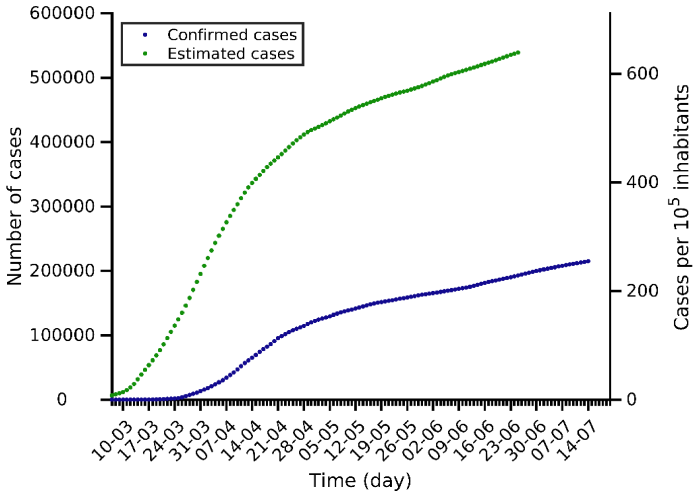


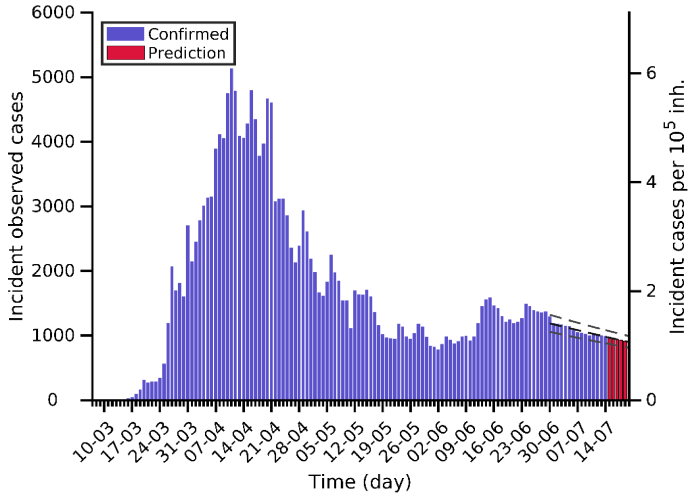


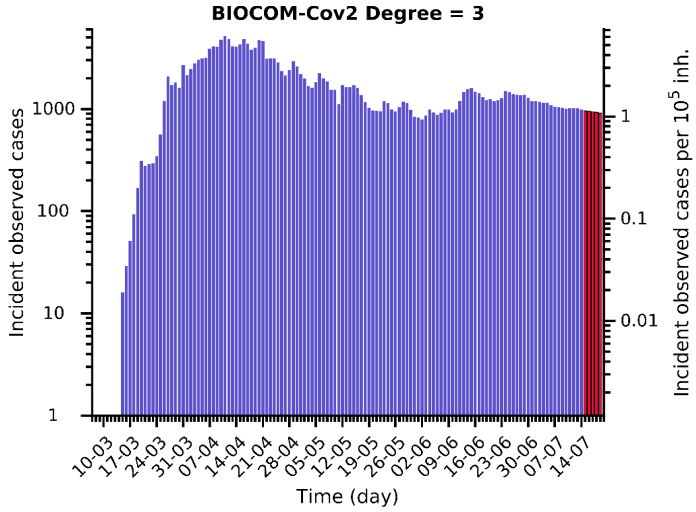


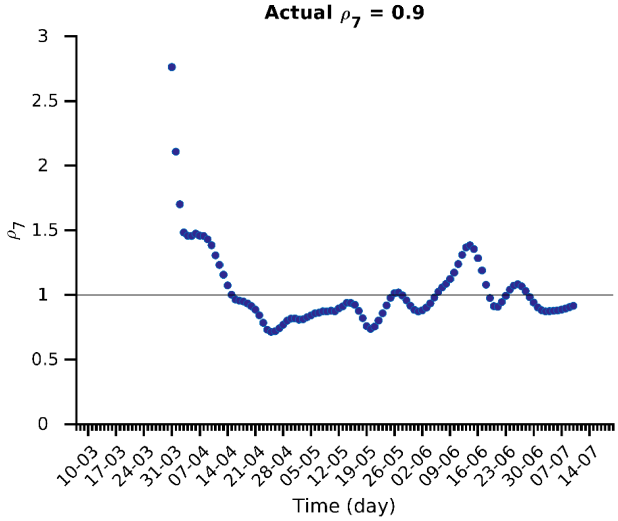
Turkey 14-07-2020. Pop: 84.3M. Cumulative incidence: 255/10⁵

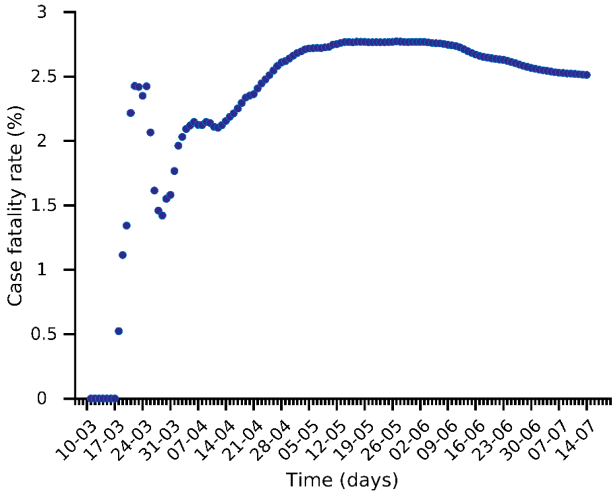


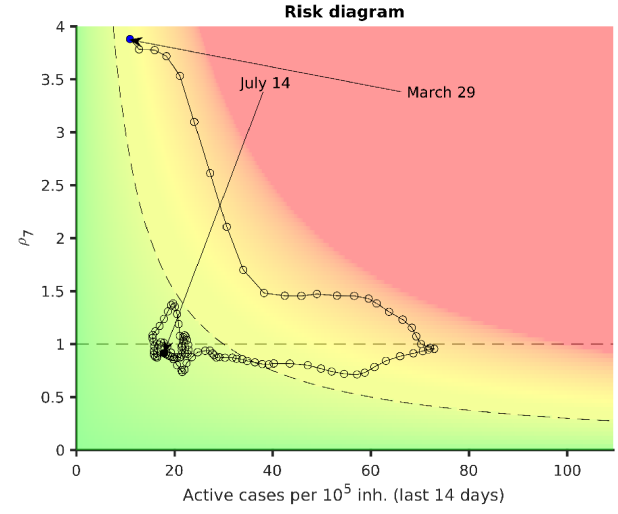


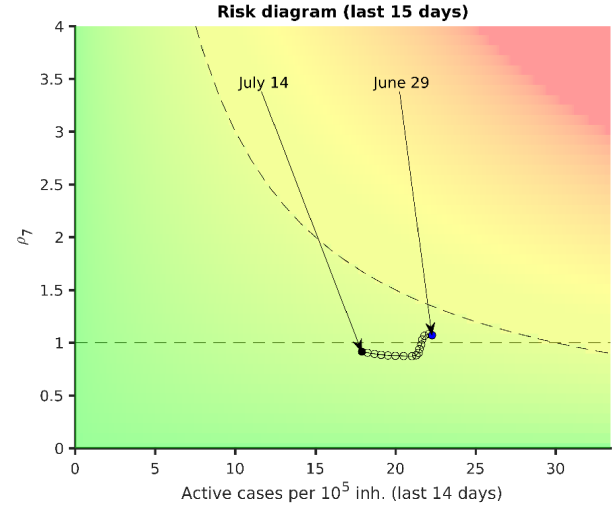




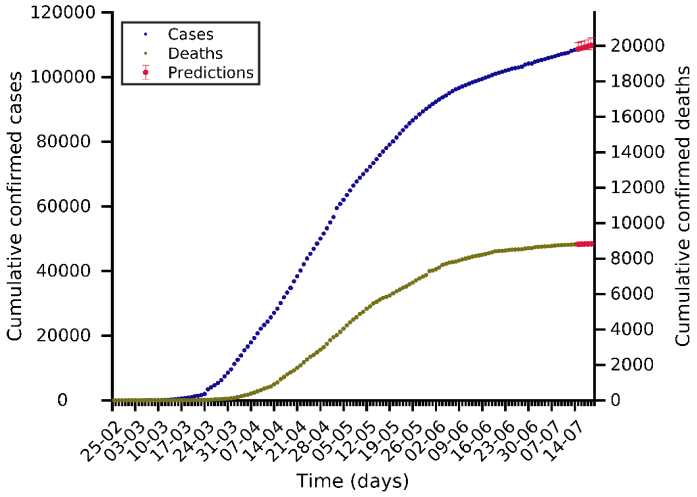


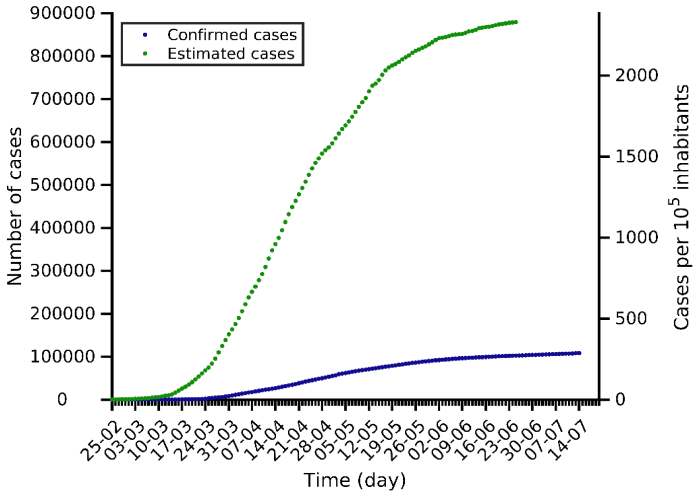


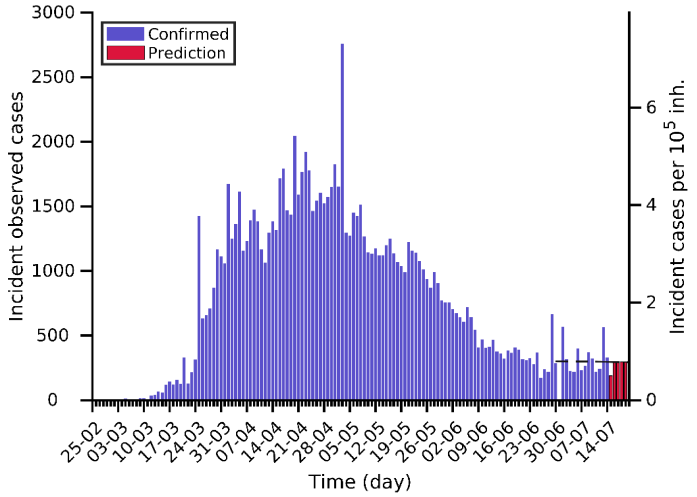


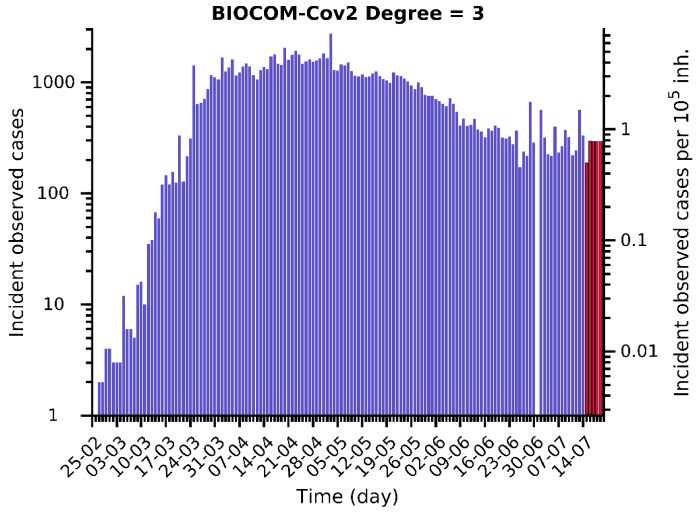


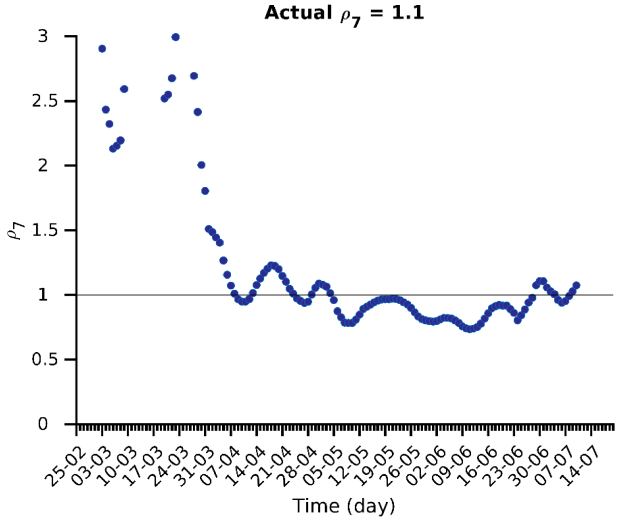
Canada 14-07-2020. Pop: 37.7M. Cumulative incidence: 287/10⁵

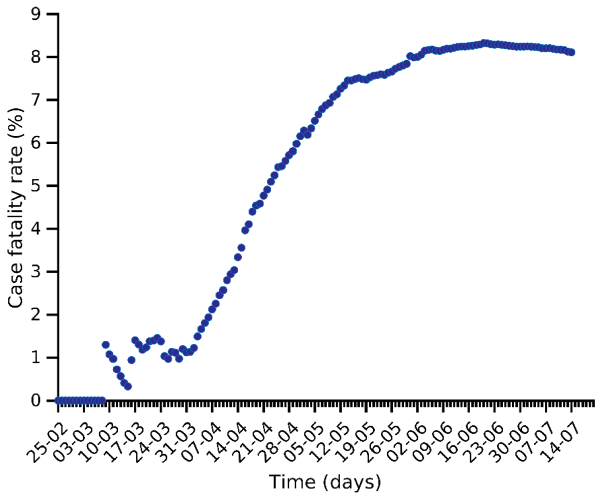


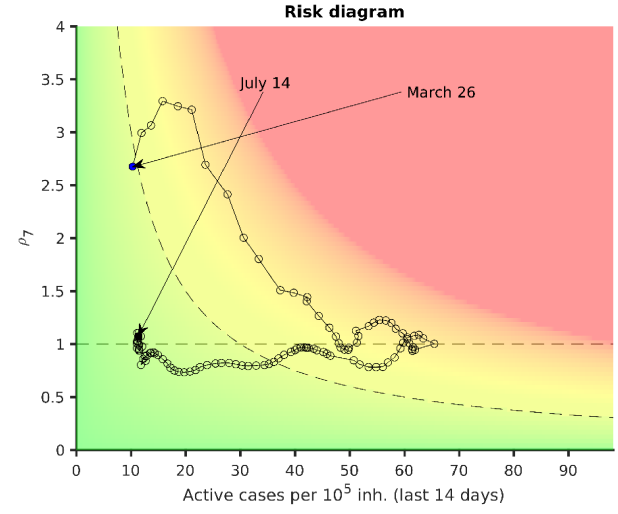


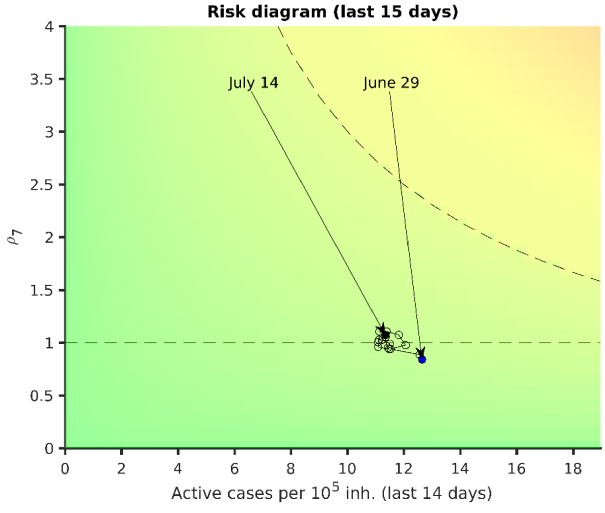




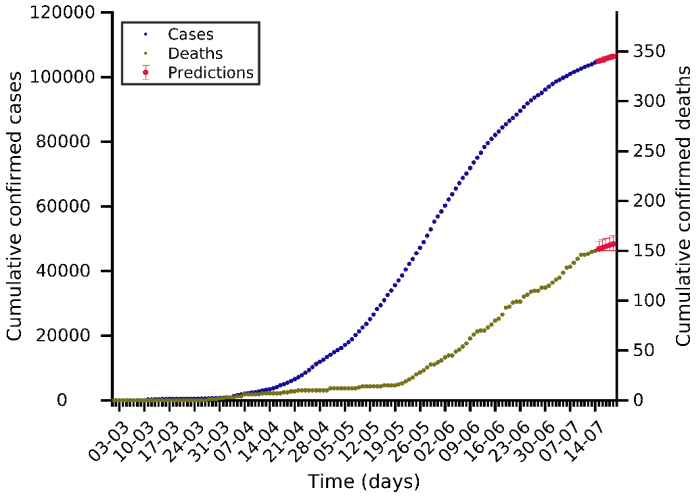


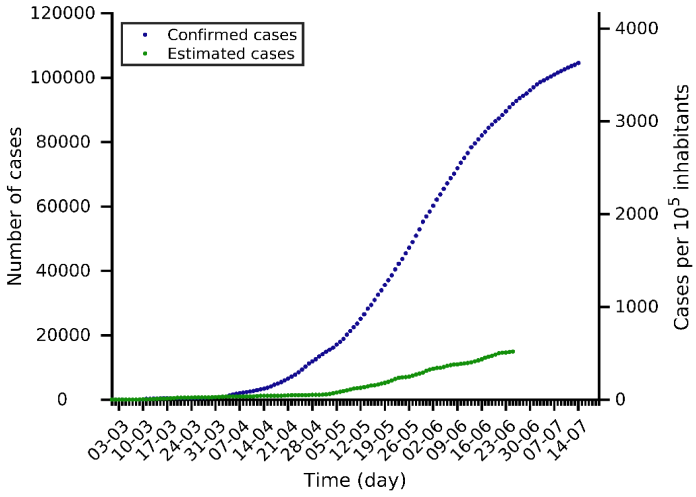


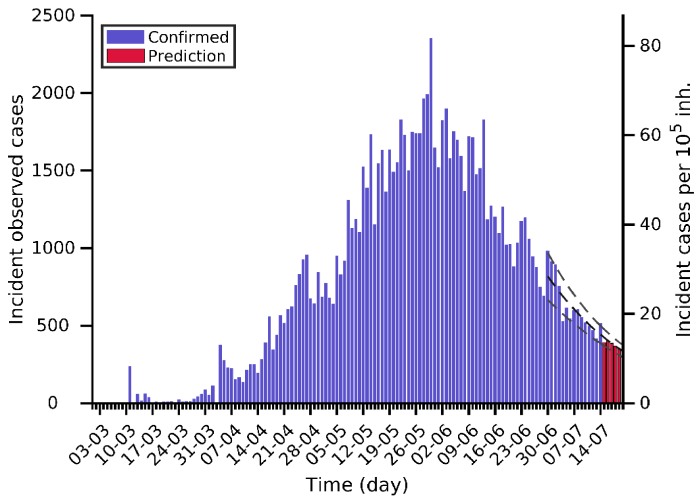


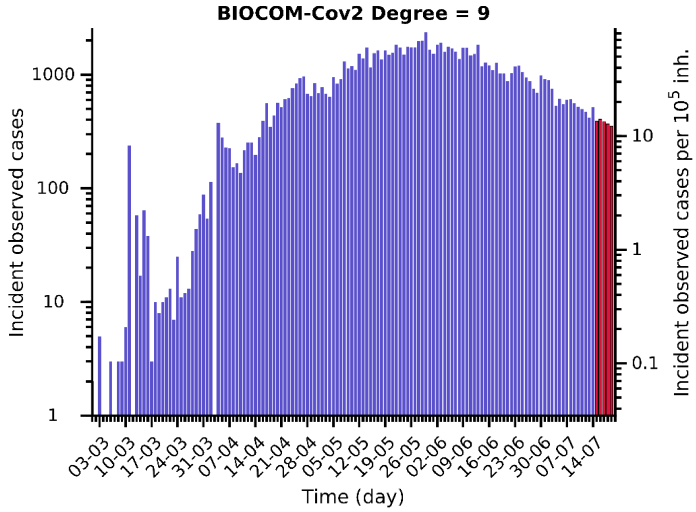


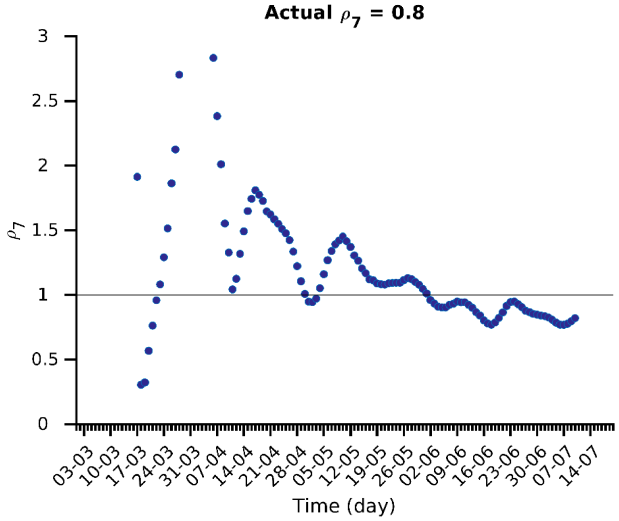
Qatar 14-07-2020. Pop: 2.9M. Cumulative incidence: 3628/10⁵

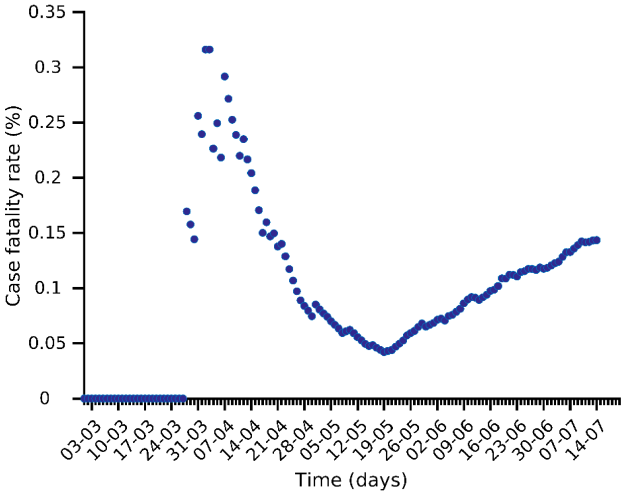


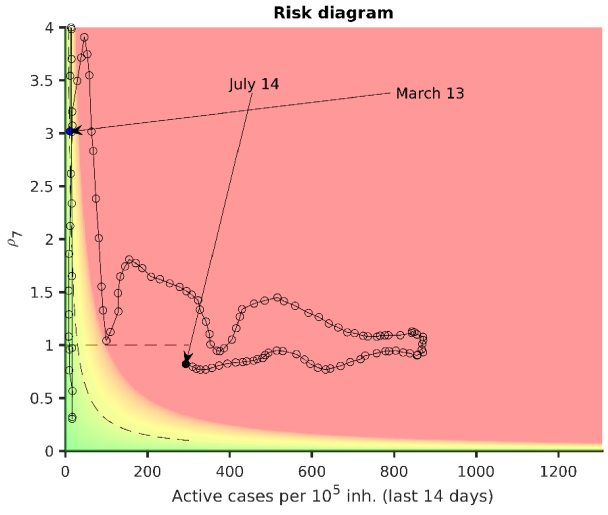


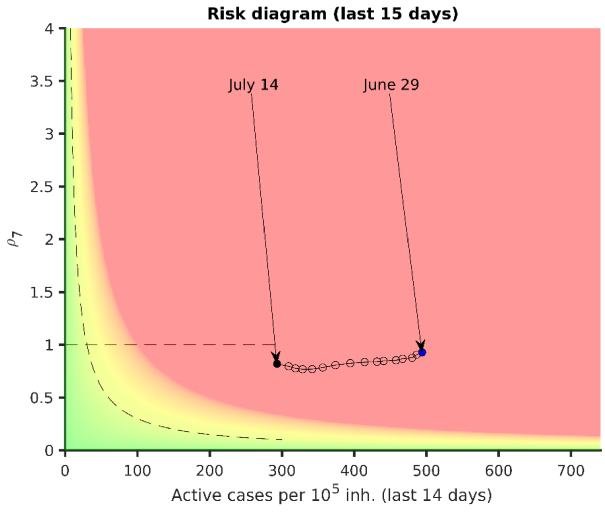




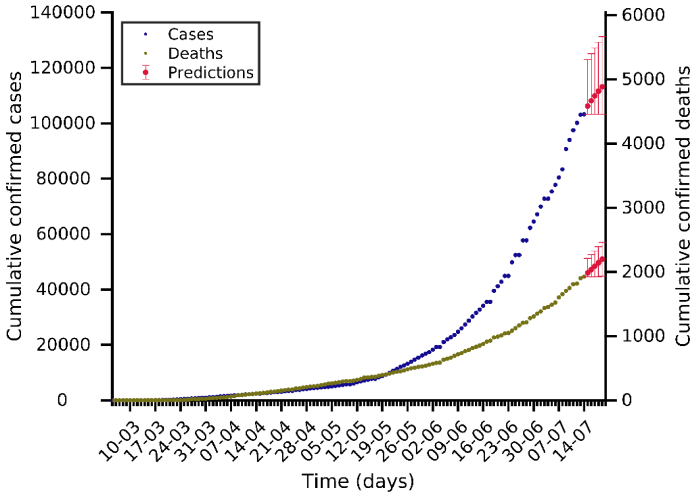


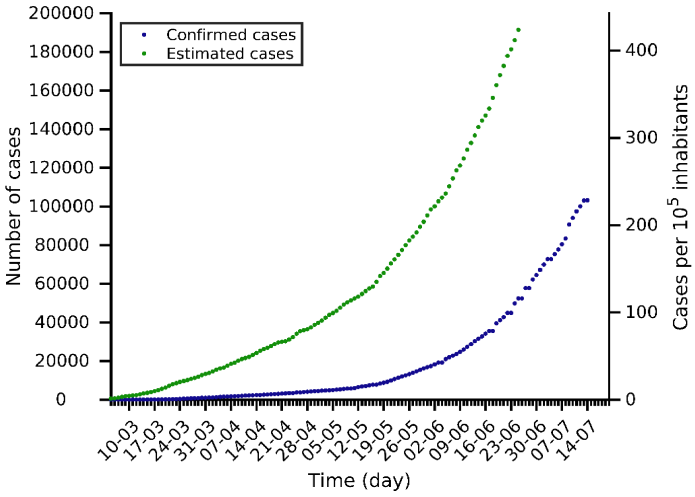


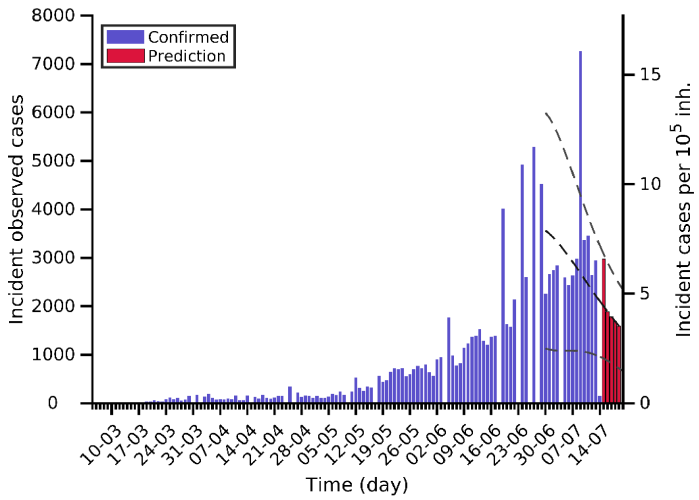


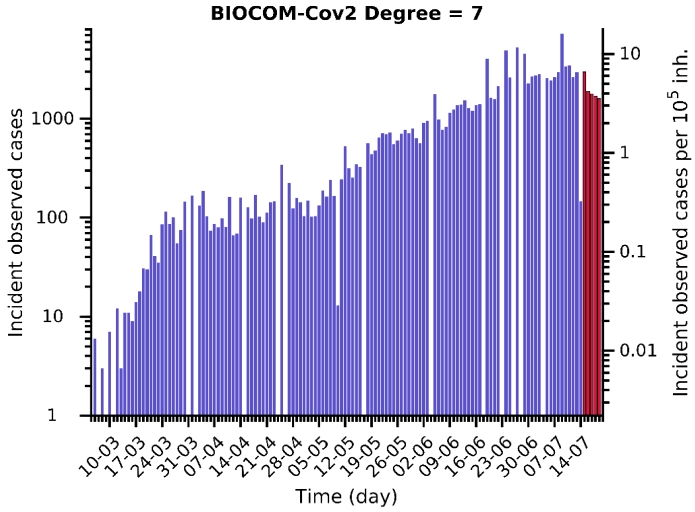


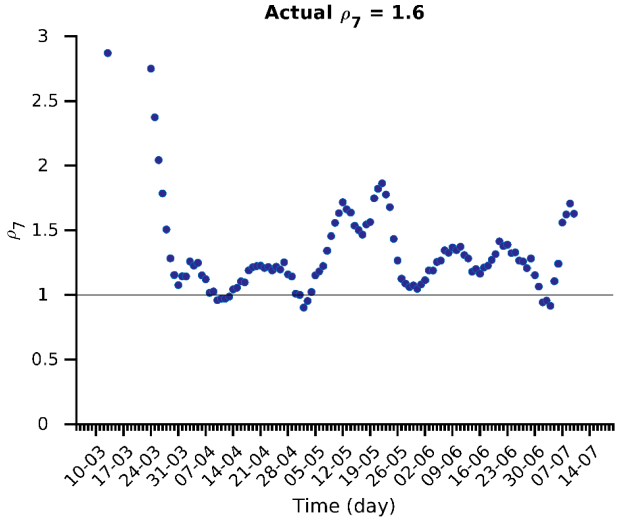
Argentina 14-07-2020. Pop: 45.2M. Cumulative incidence: 228/10⁵

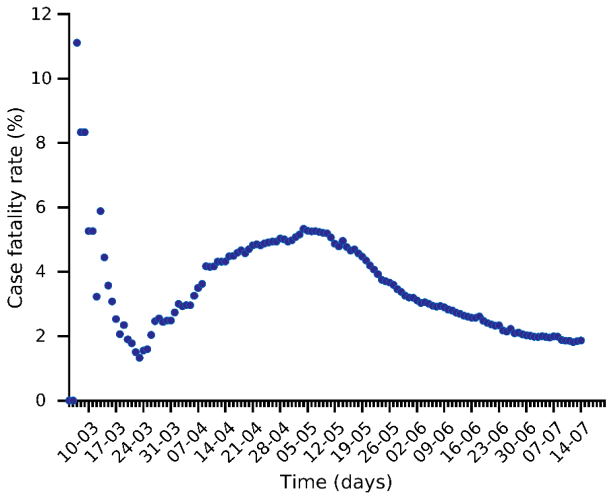


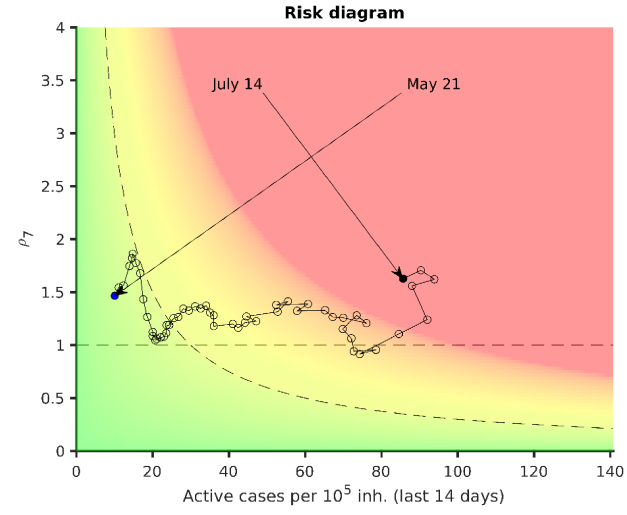


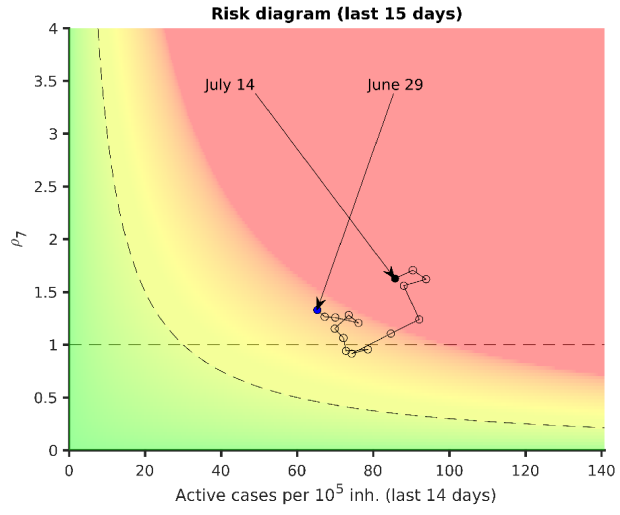




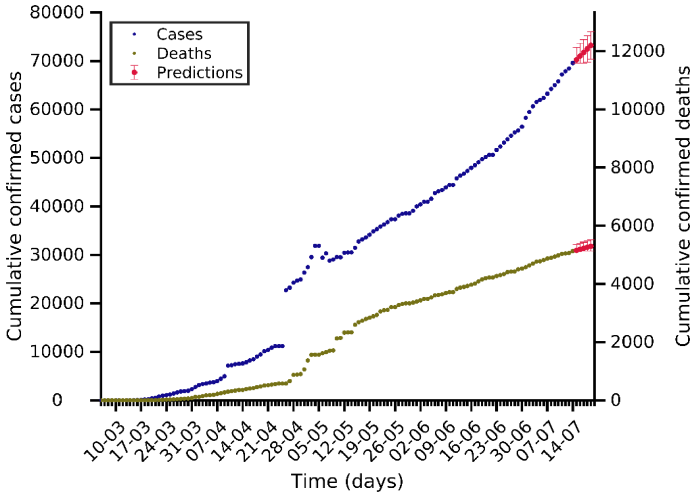


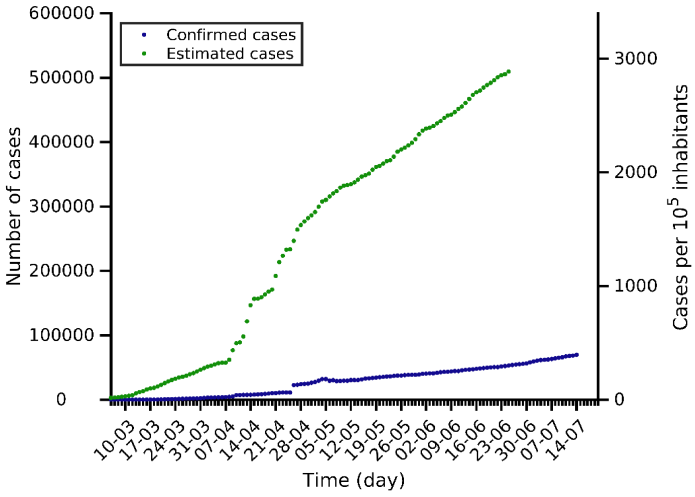


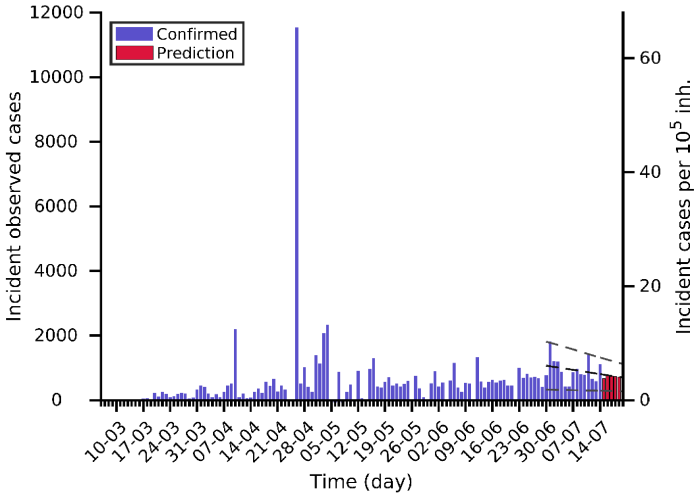


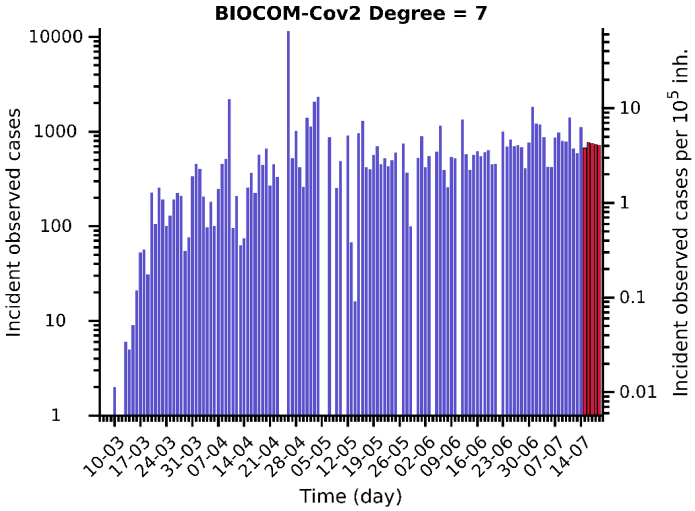


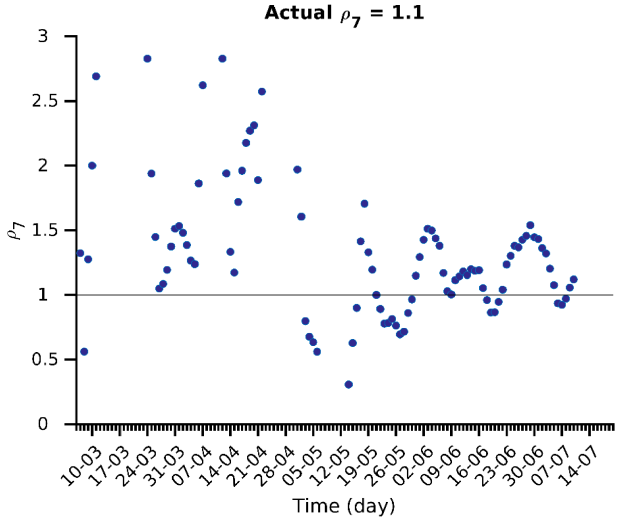
Ecuador 14-07-2020. Pop: 17.6M. Cumulative incidence: 394/10⁵

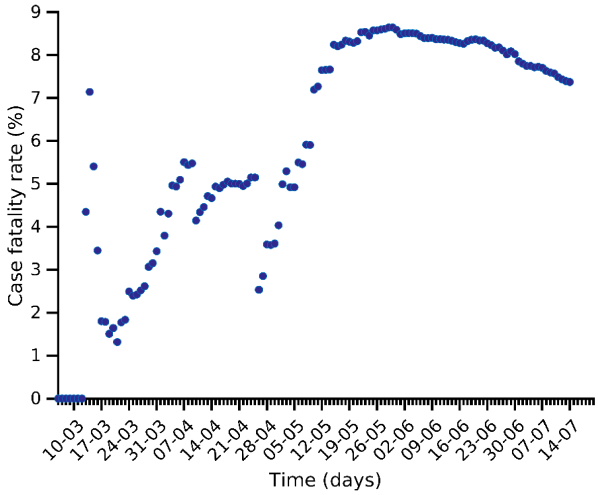


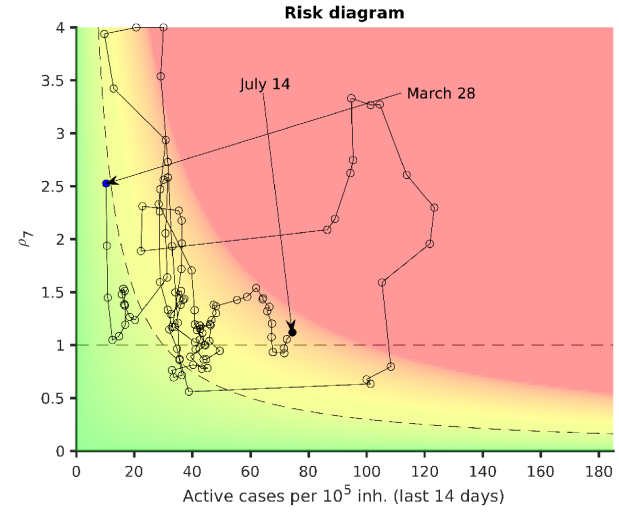


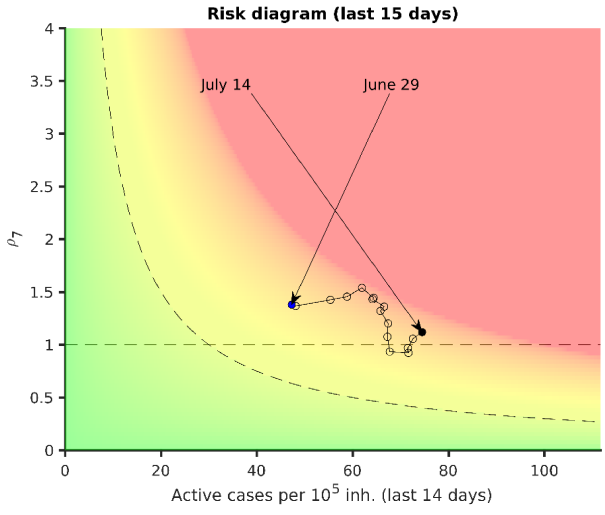




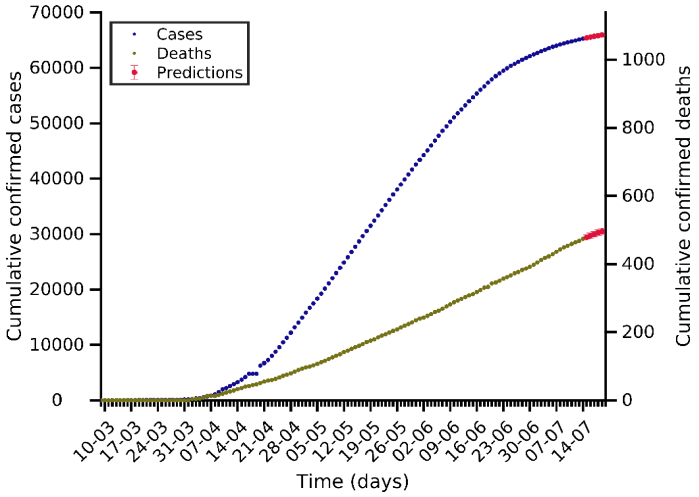


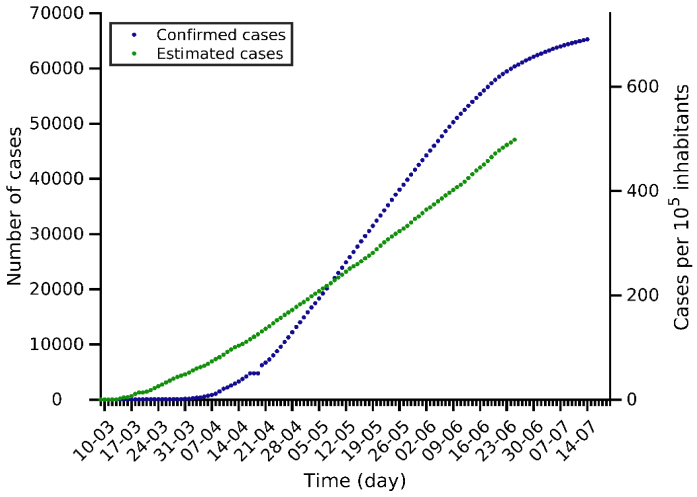


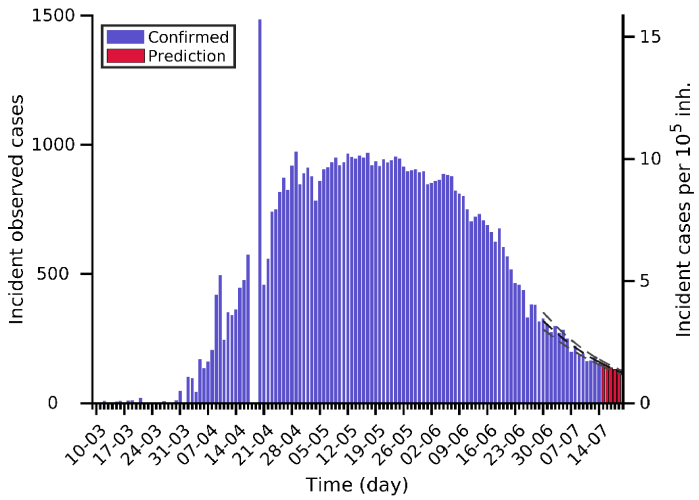


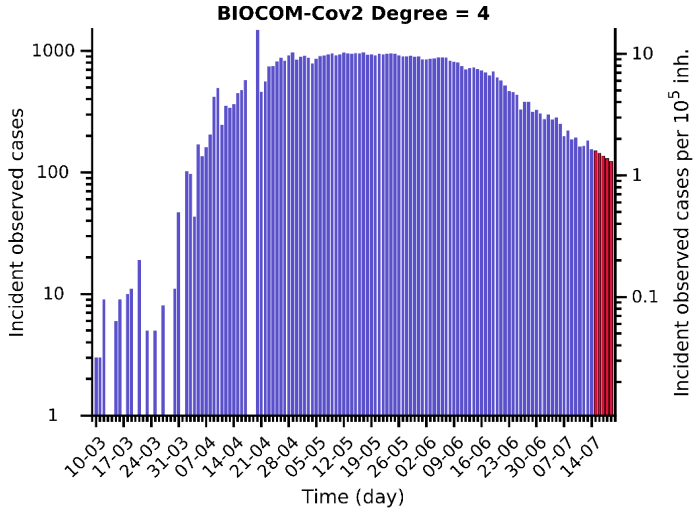


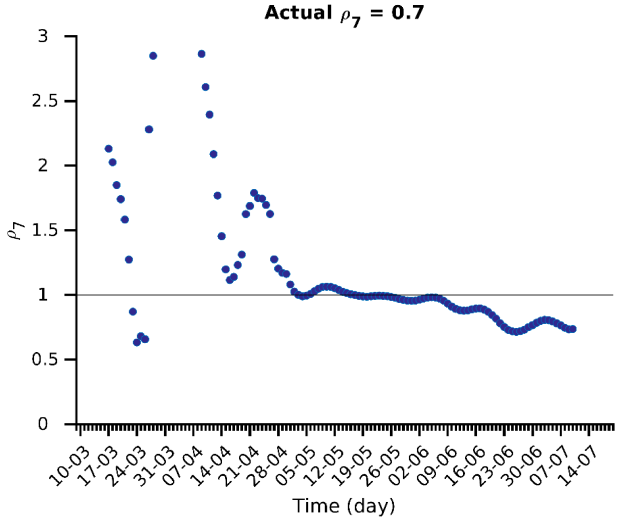
Belarus 14-07-2020. Pop: 9.4M. Cumulative incidence: 691/10^5

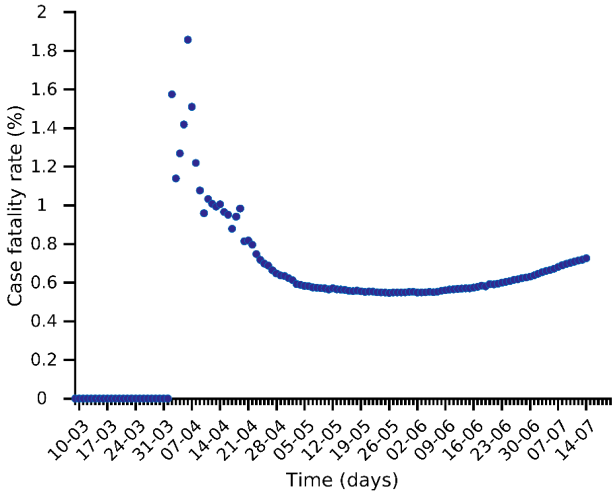


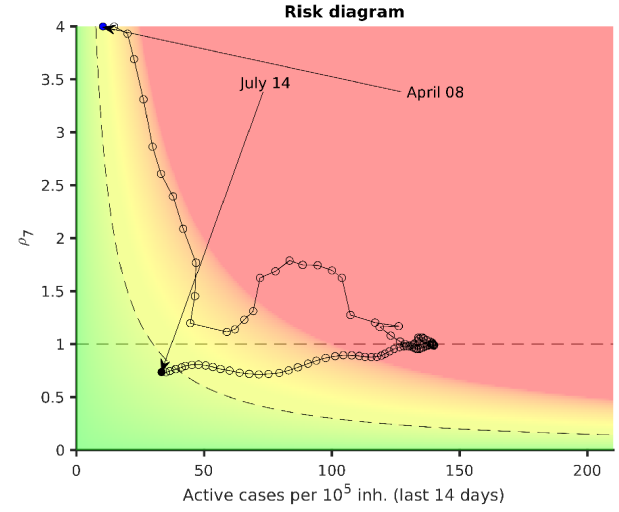


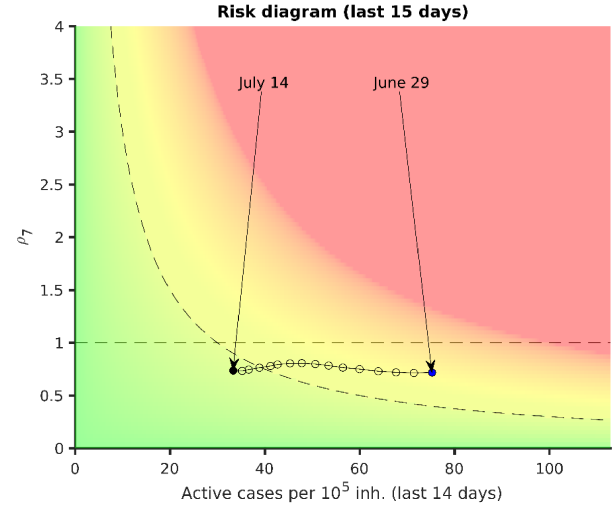




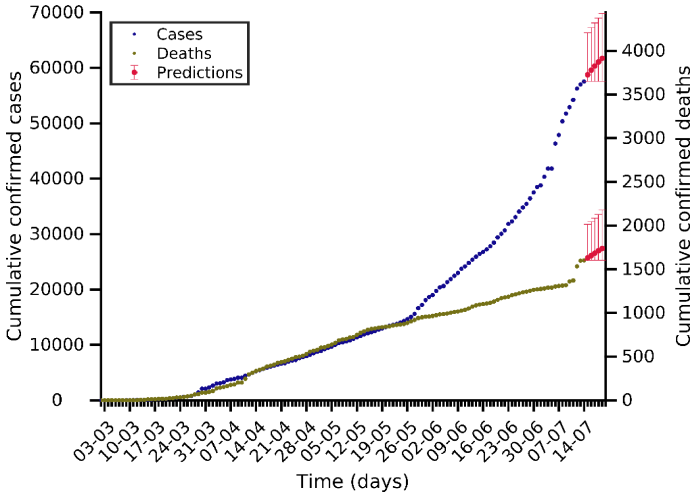


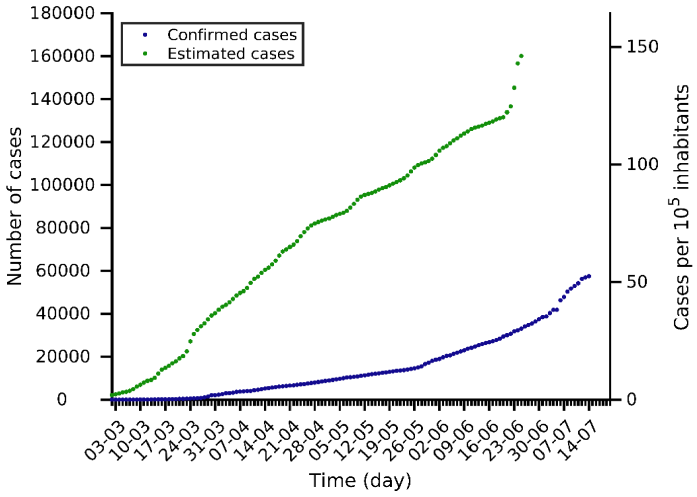


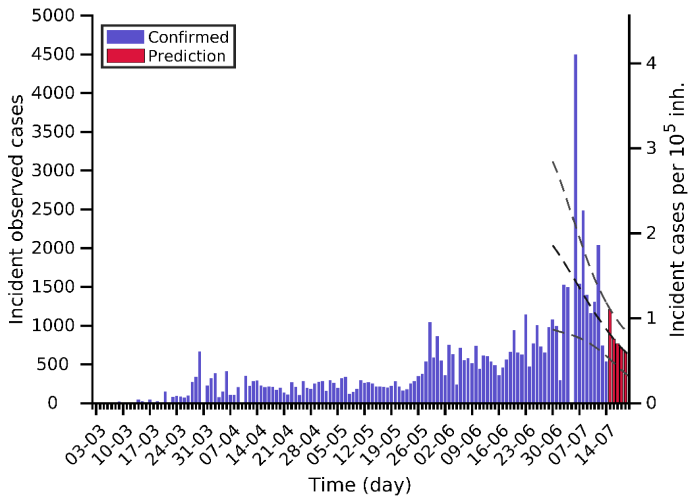


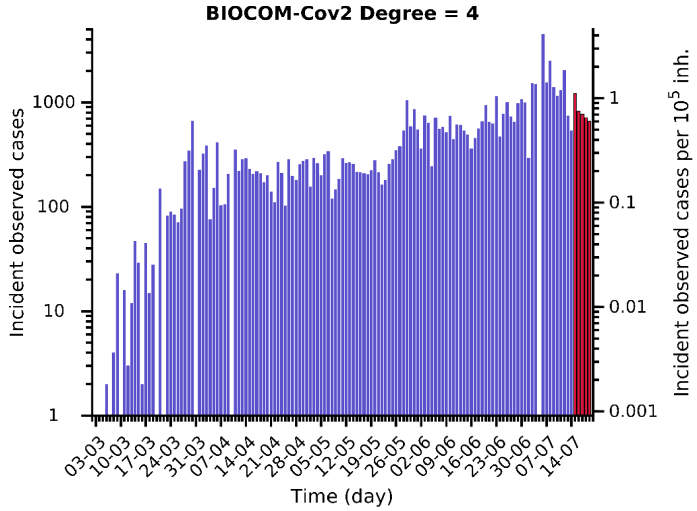


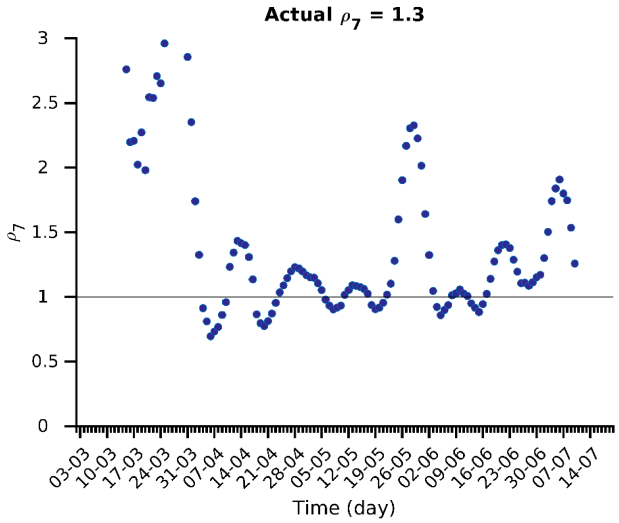
Philippines 14-07-2020. Pop: 109.6M. Cumulative incidence: 53/10⁵

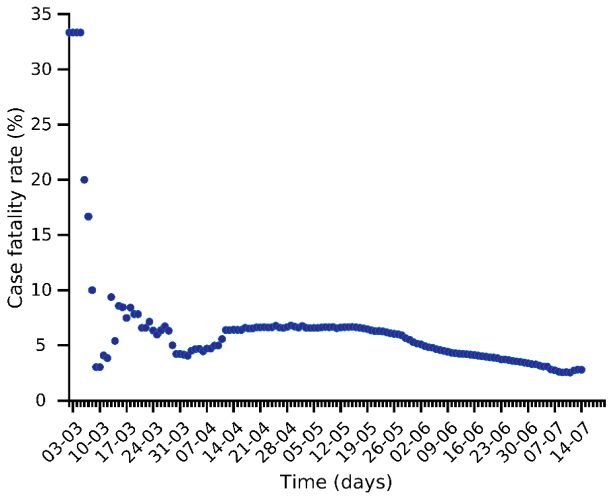


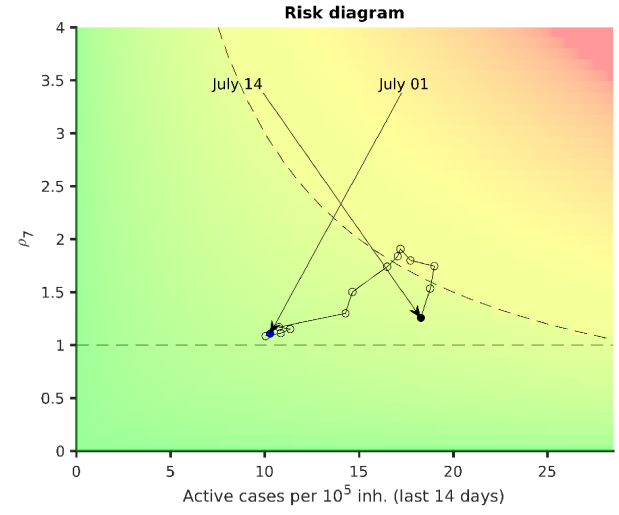


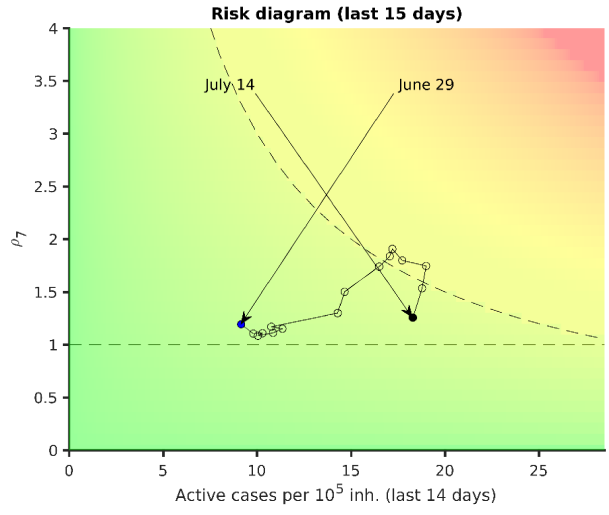




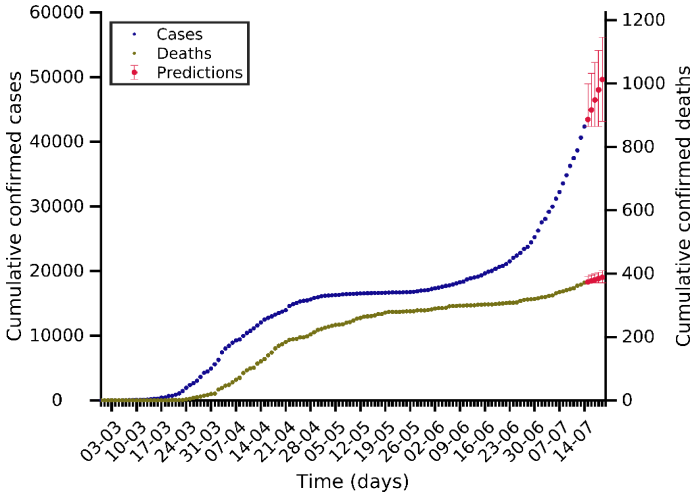


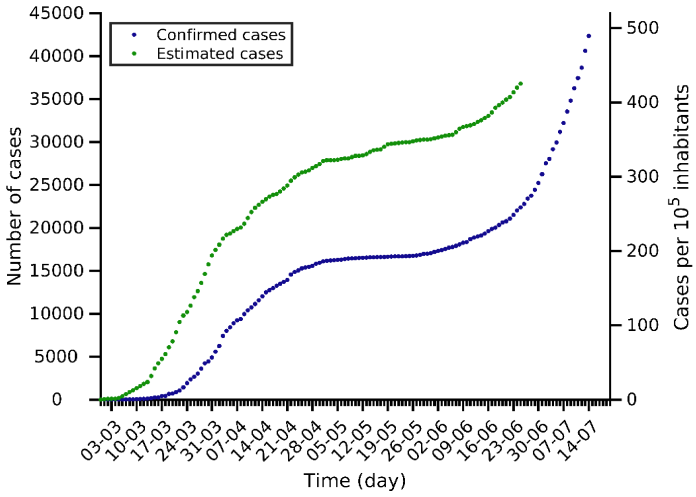


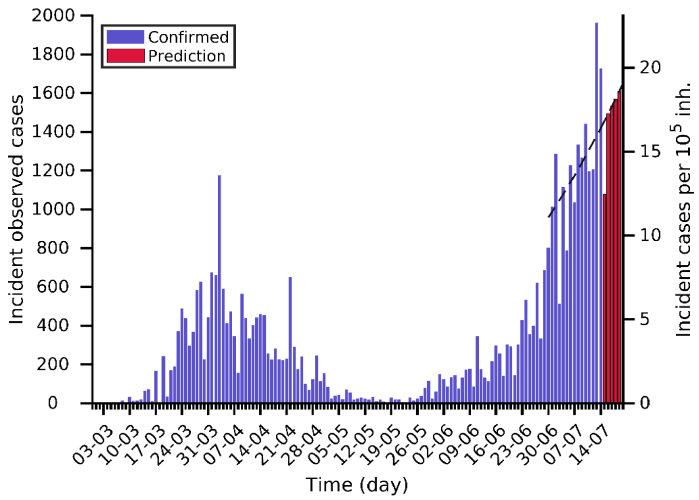


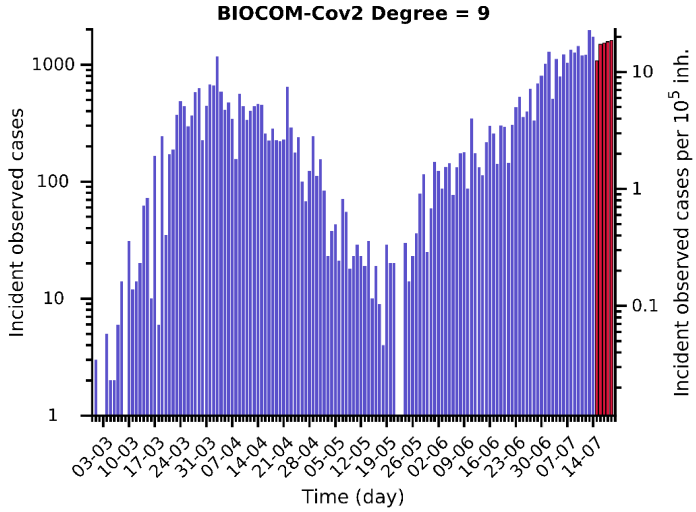


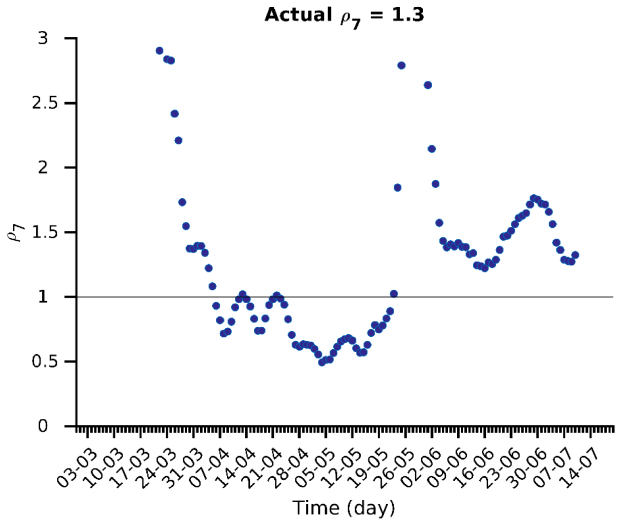
Israel 14-07-2020. Pop: 8.7M. Cumulative incidence: 489/10⁵

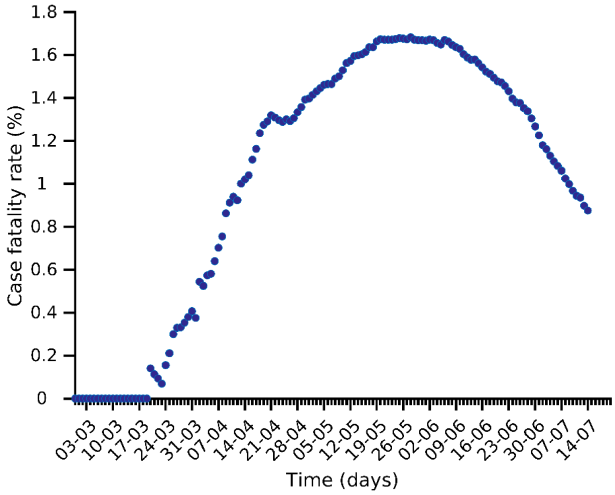


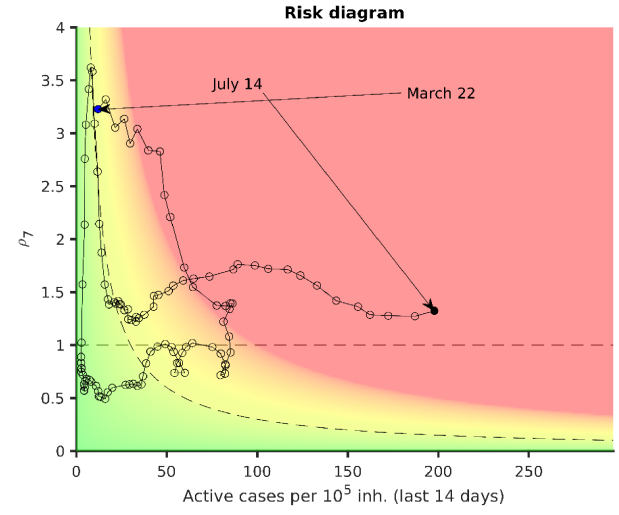


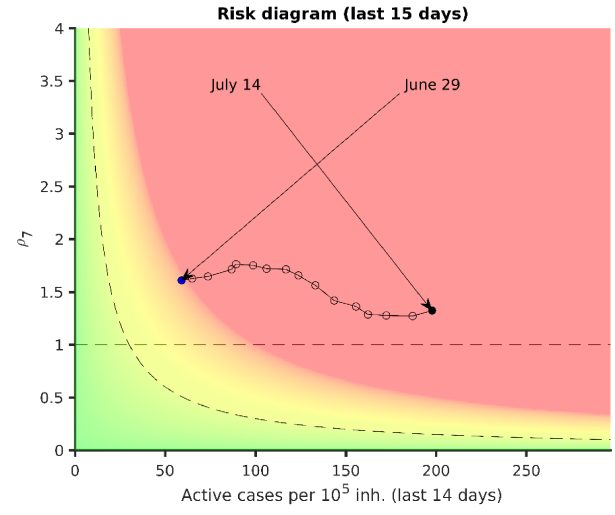




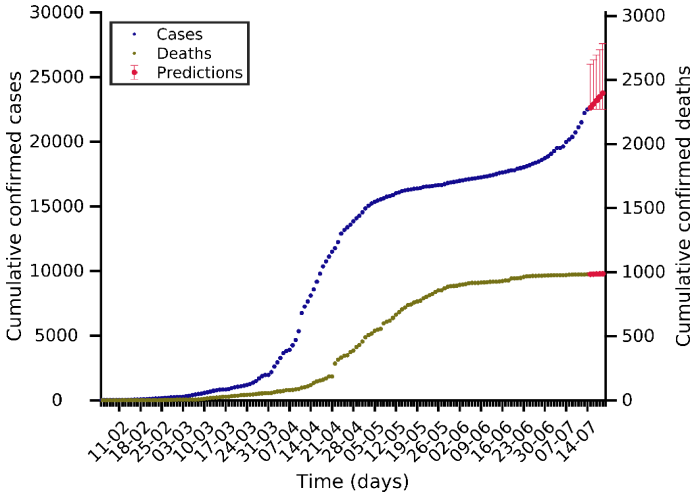


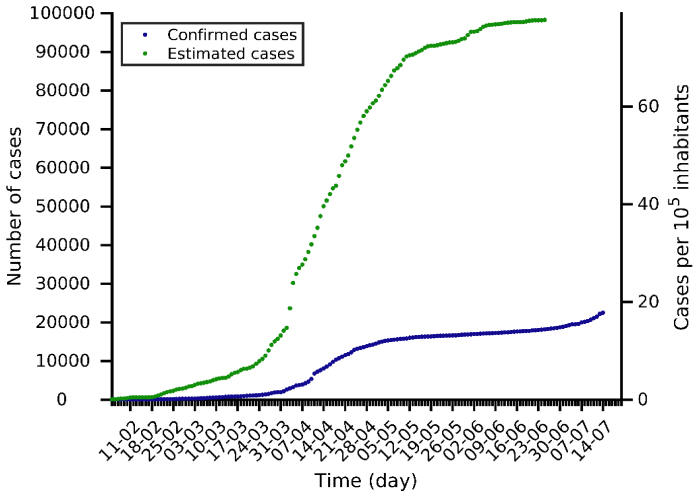


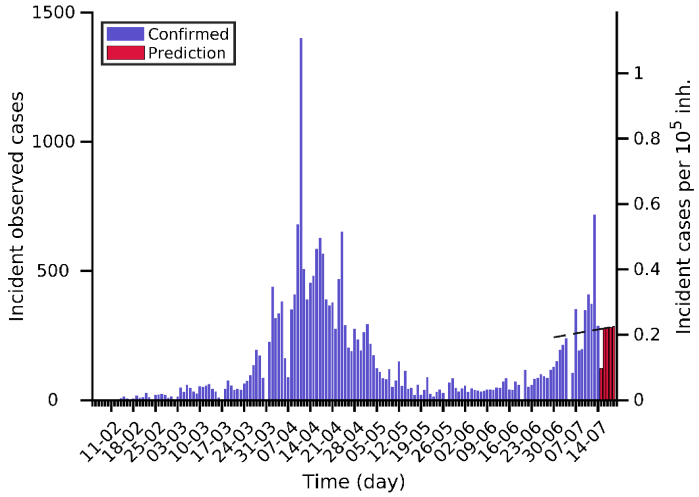


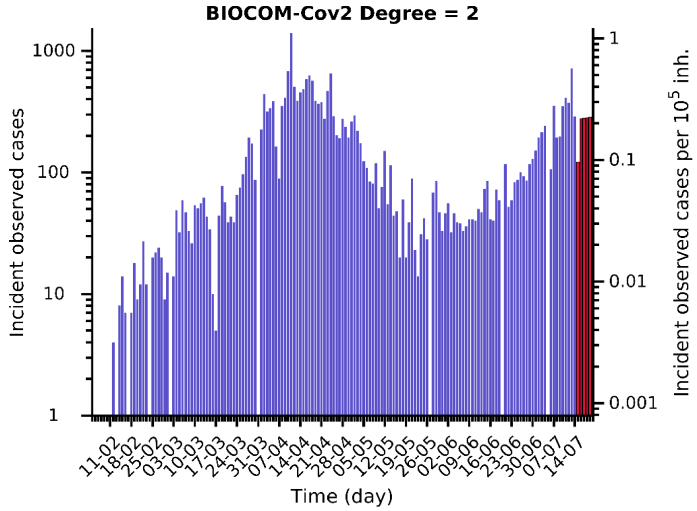


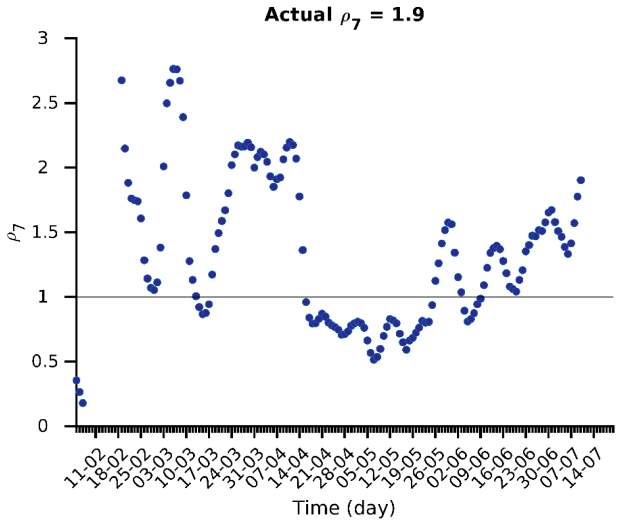
Japan 14-07-2020. Pop: 126.5M. Cumulative incidence: 18/10^5

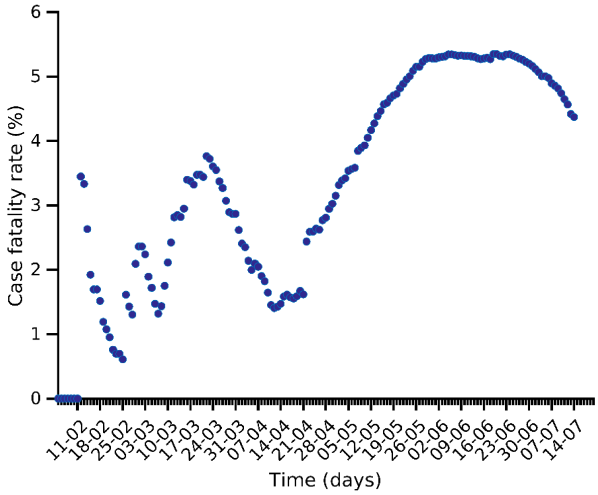


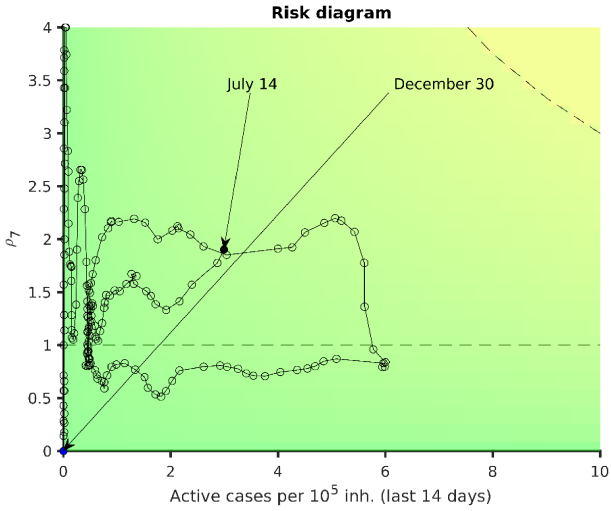


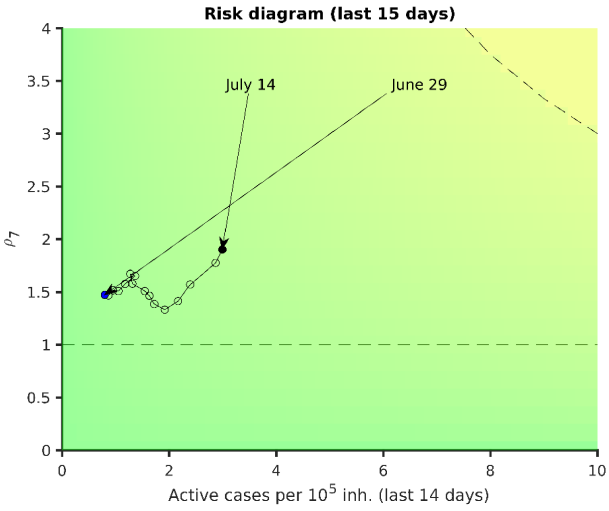




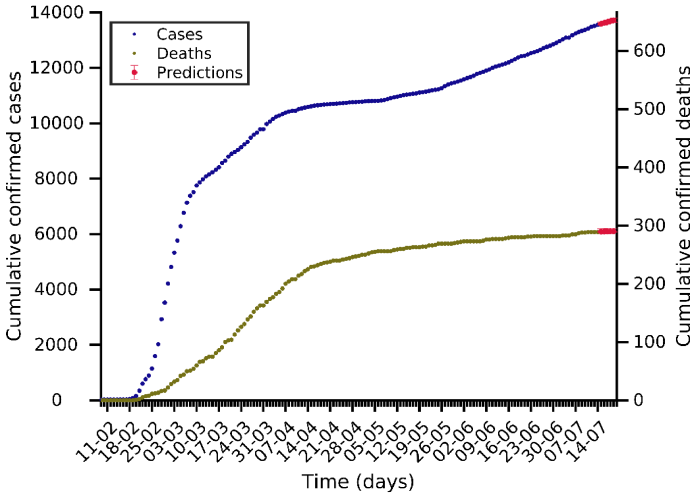


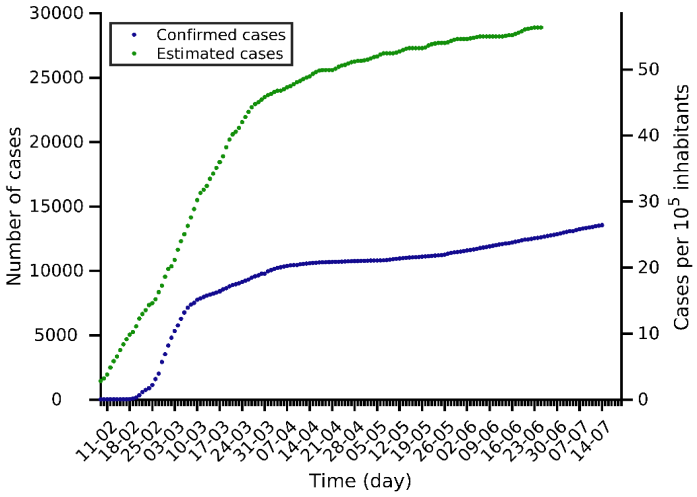


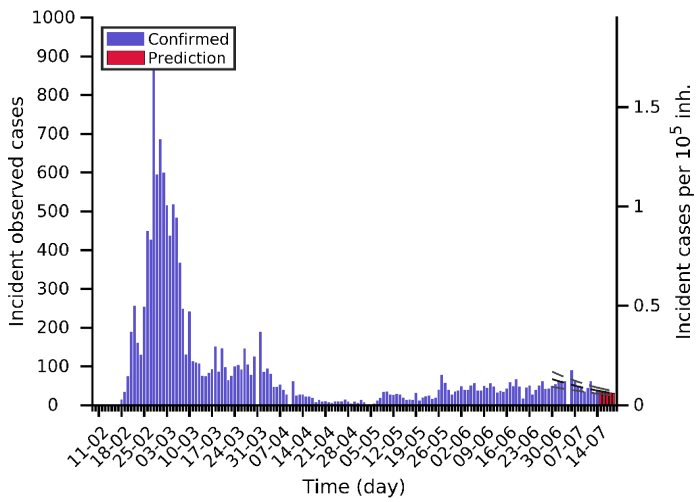


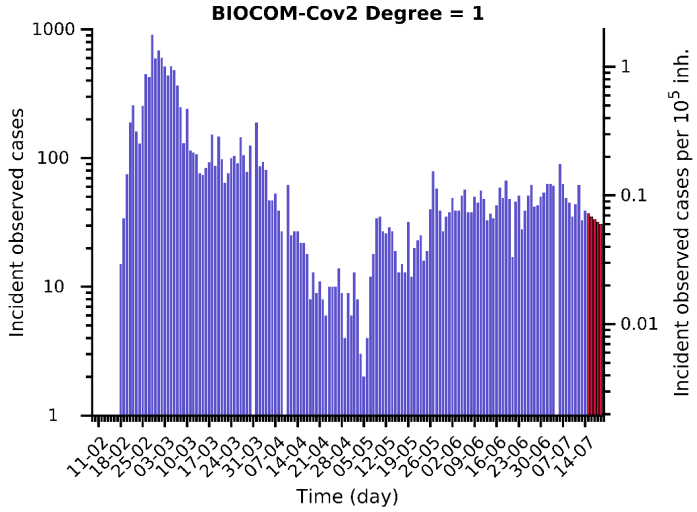


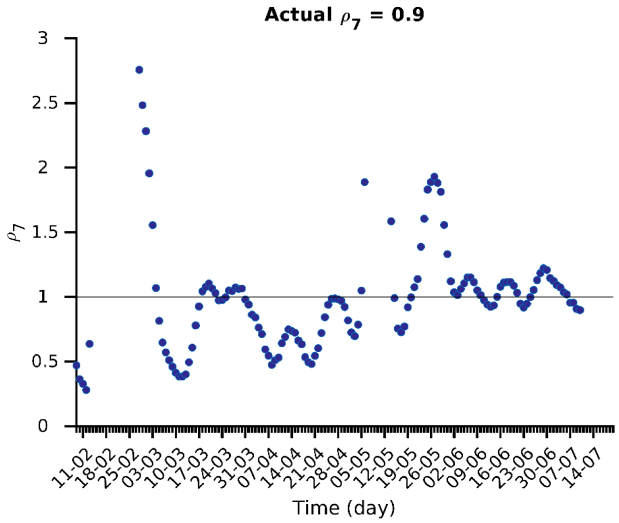
South Korea 14-07-2020. Pop: 51.3M. Cumulative incidence: 26/10^5

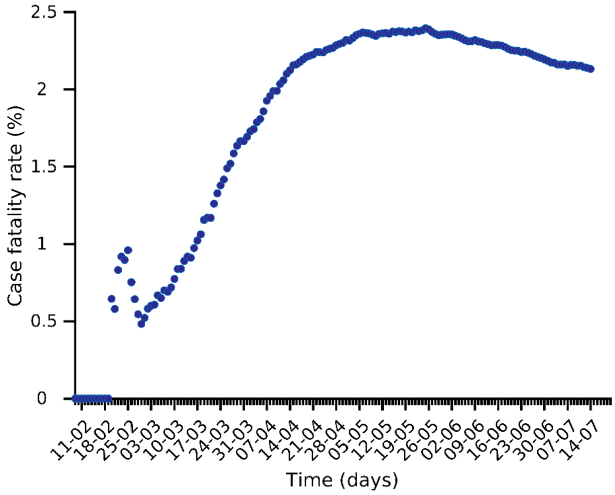


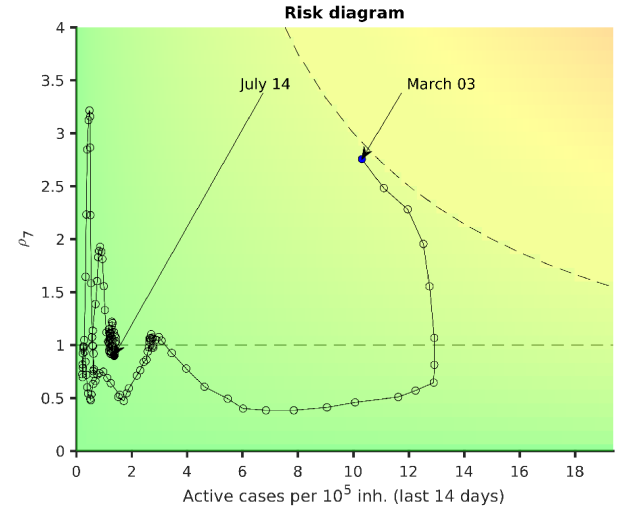


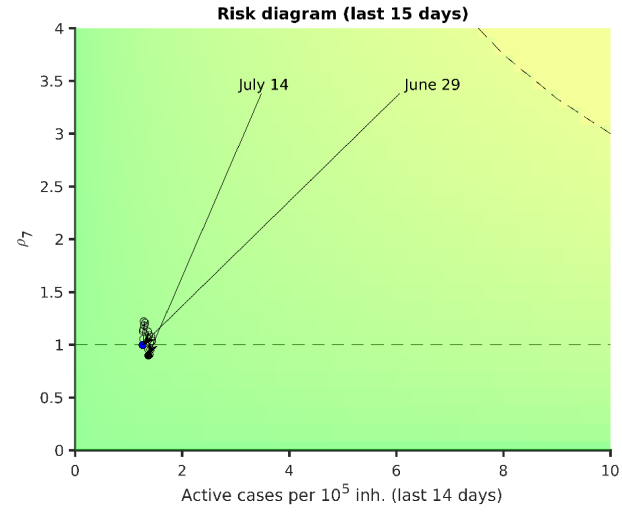




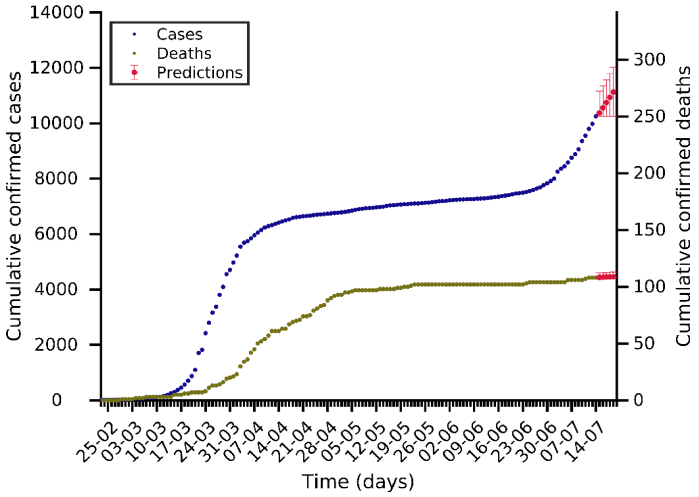


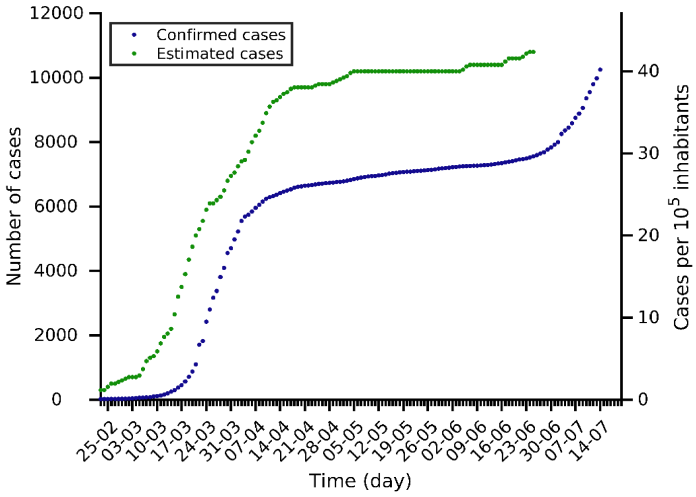


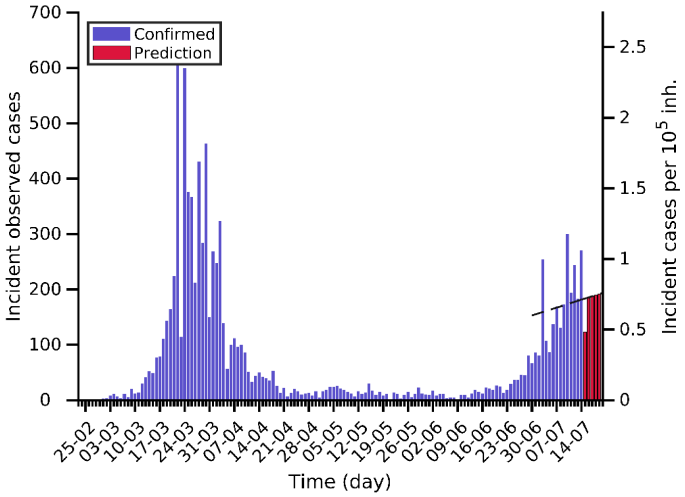


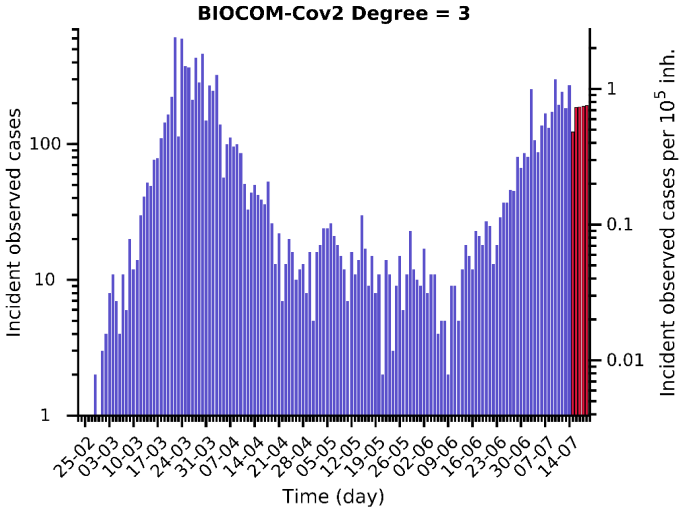


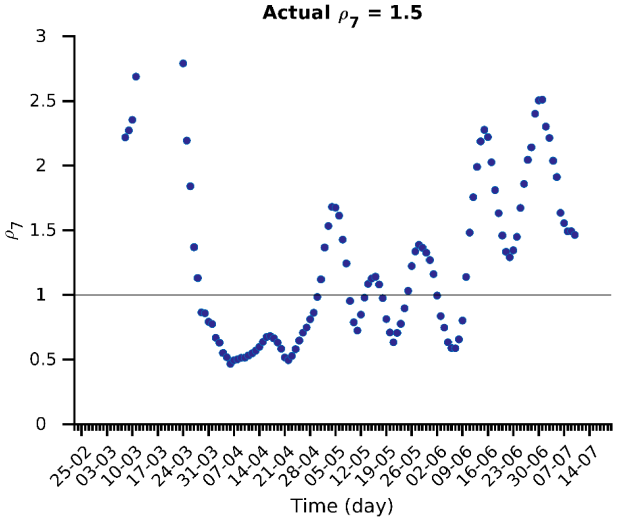
Australia 14-07-2020. Pop: 25.5M. Cumulative incidence: 40/10⁵

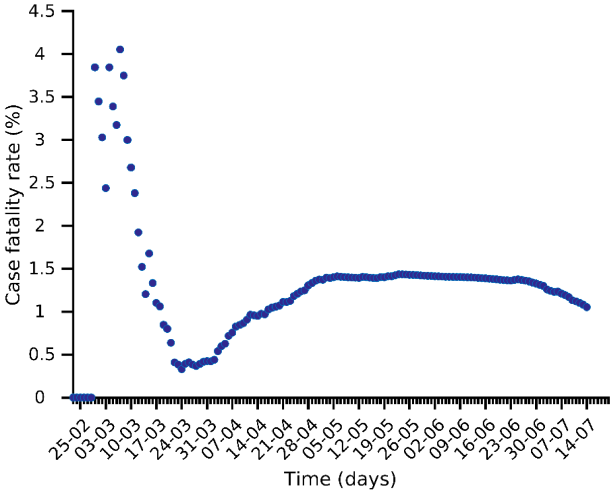


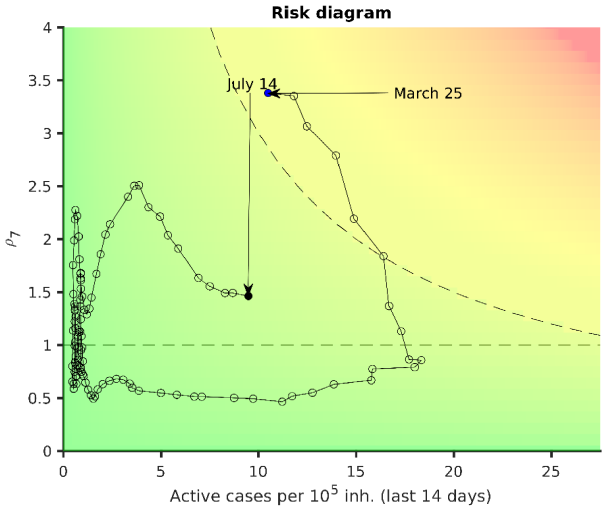


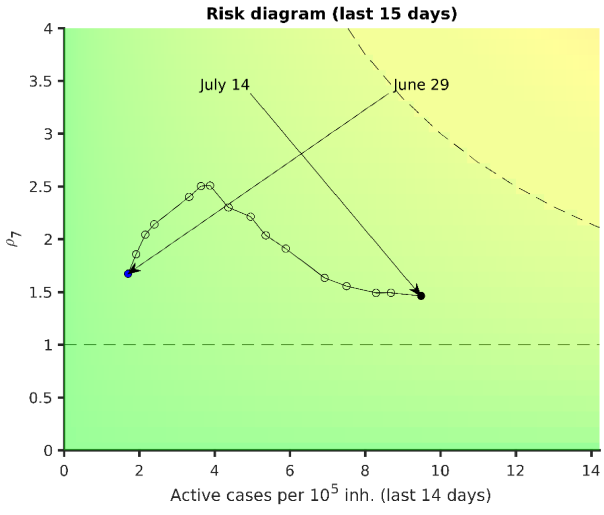




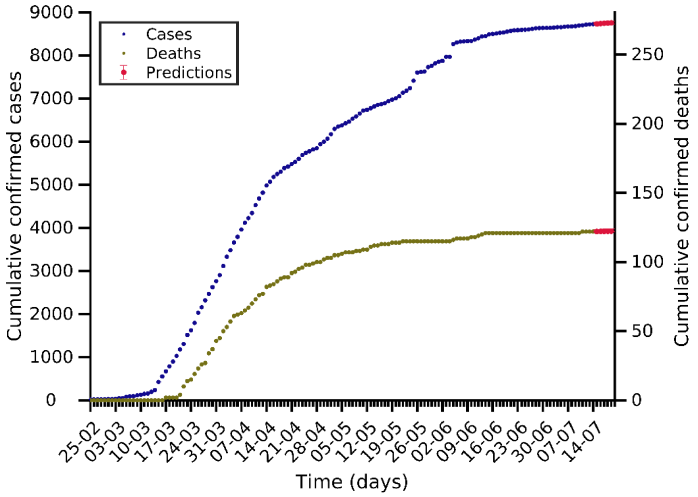


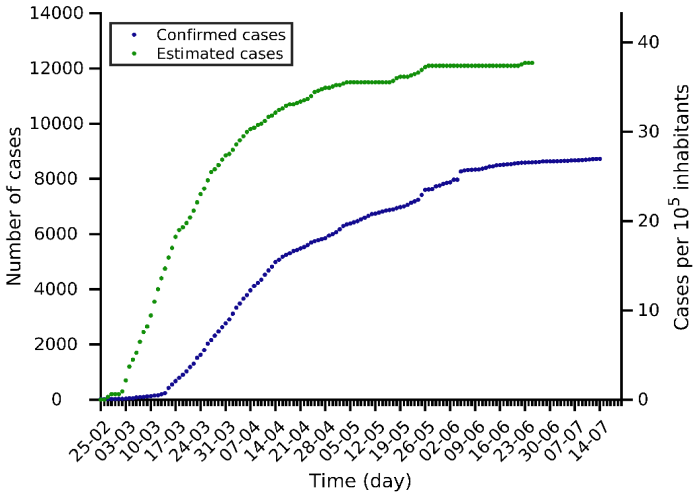


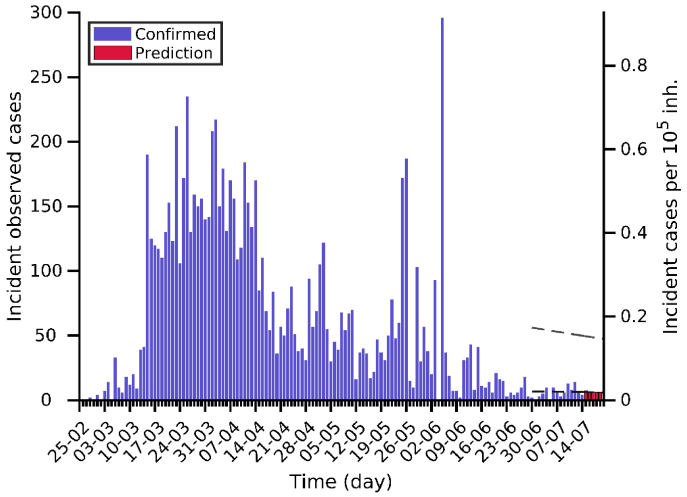


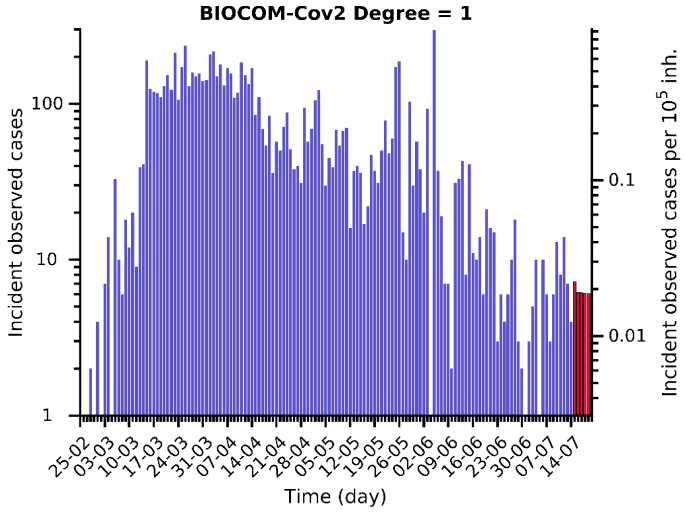


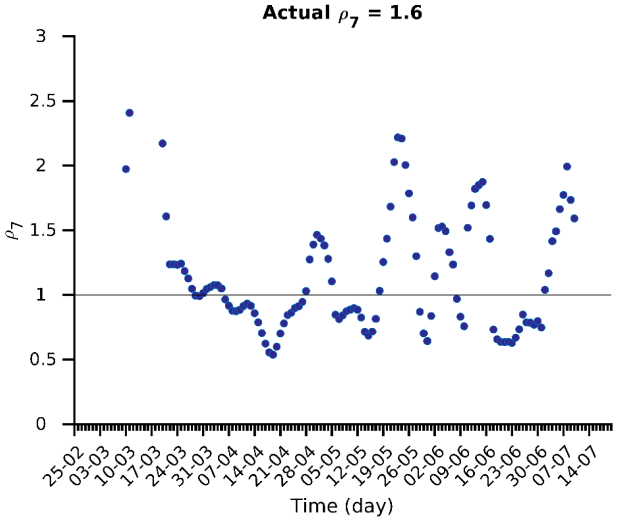
Malaysia 14-07-2020. Pop: 32.4M. Cumulative incidence: 27/10⁵

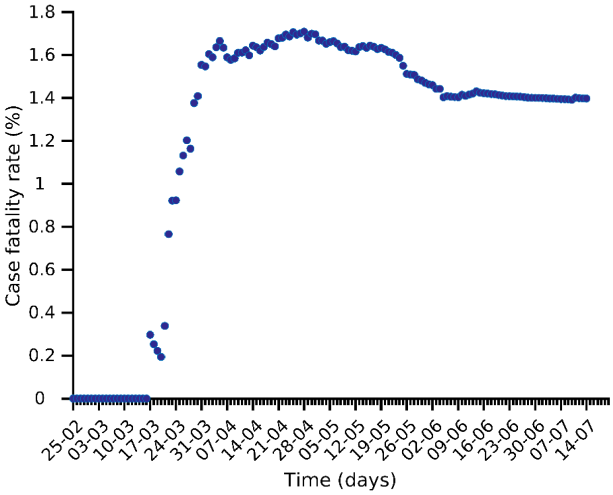


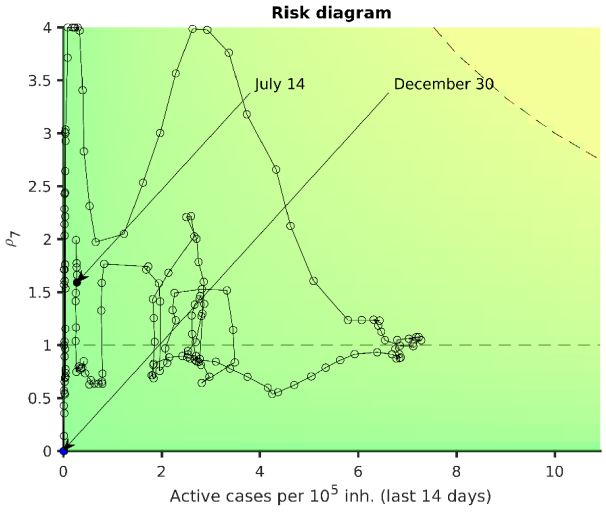


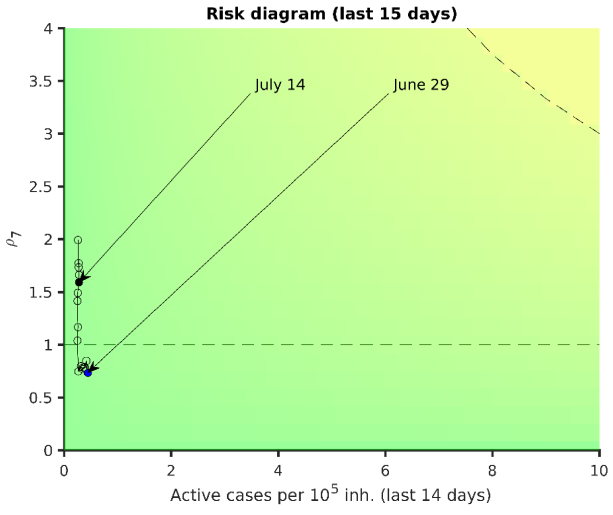




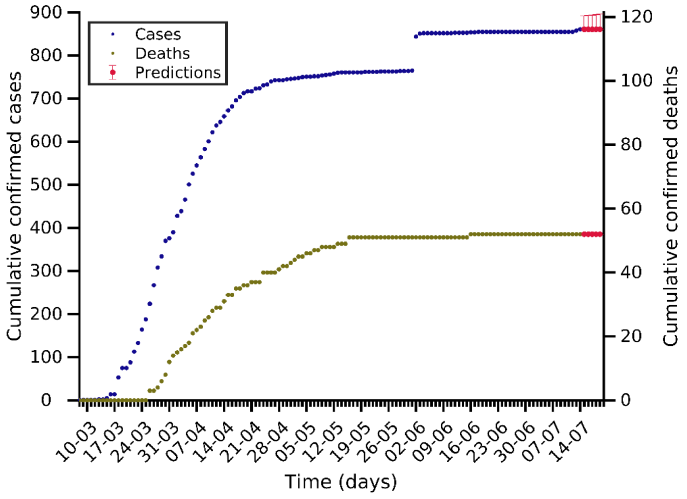


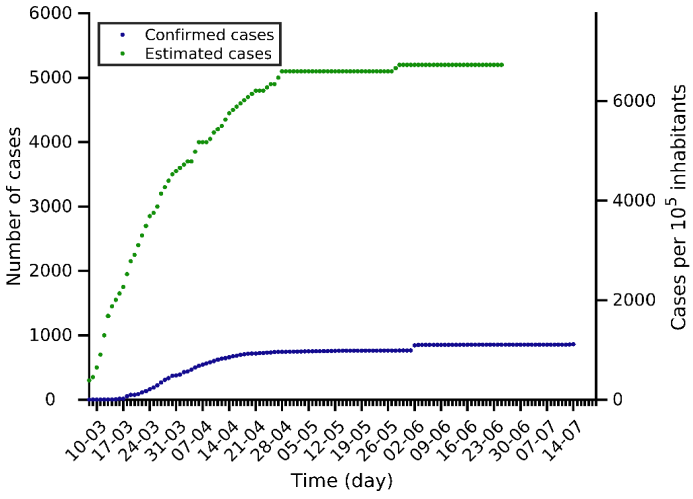


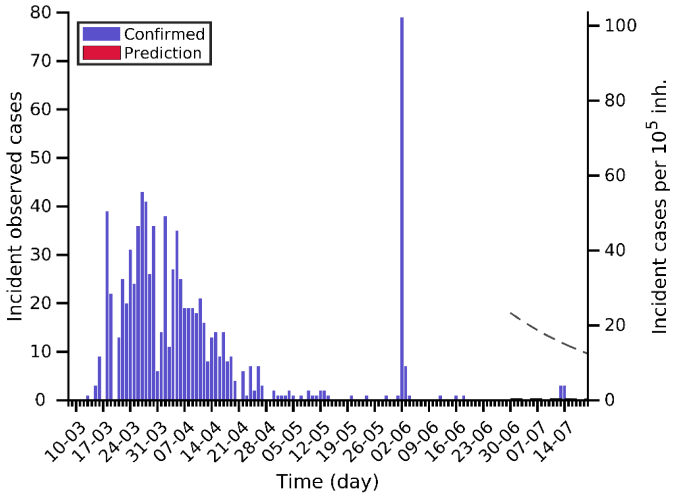


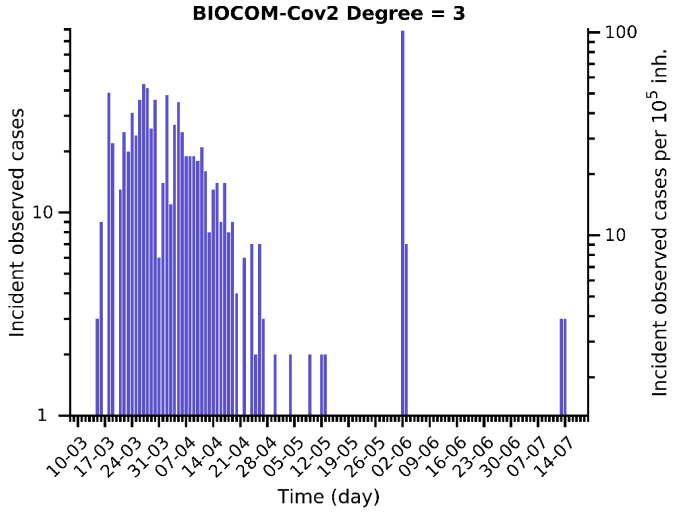


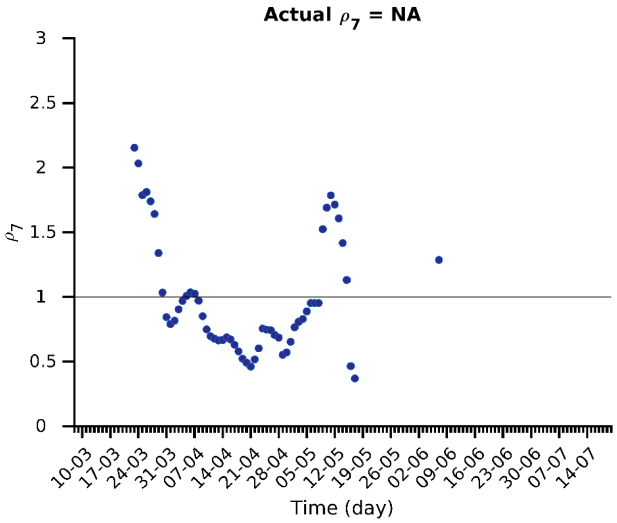
Andorra 14-07-2020. Pop: 0.1M. Cumulative incidence: 1114/10^5

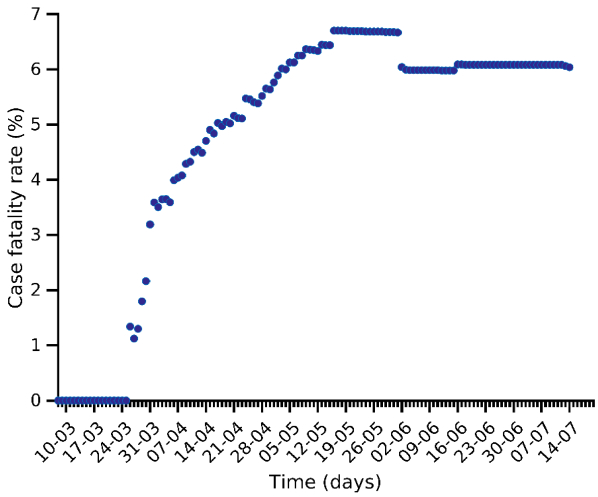


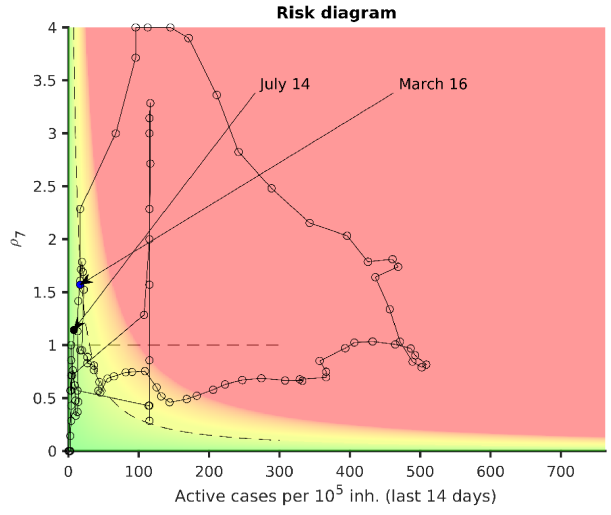


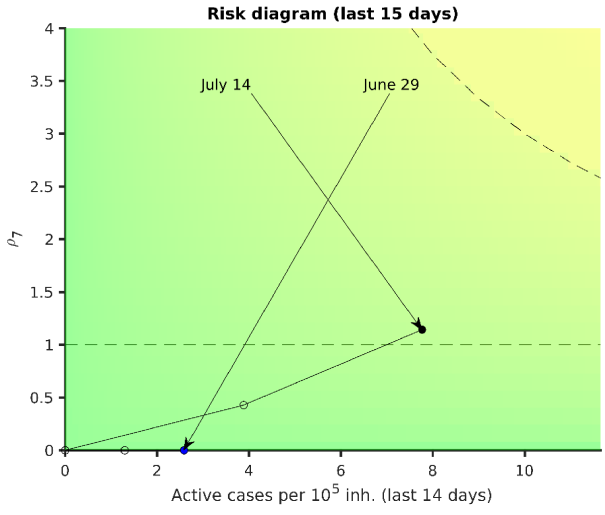










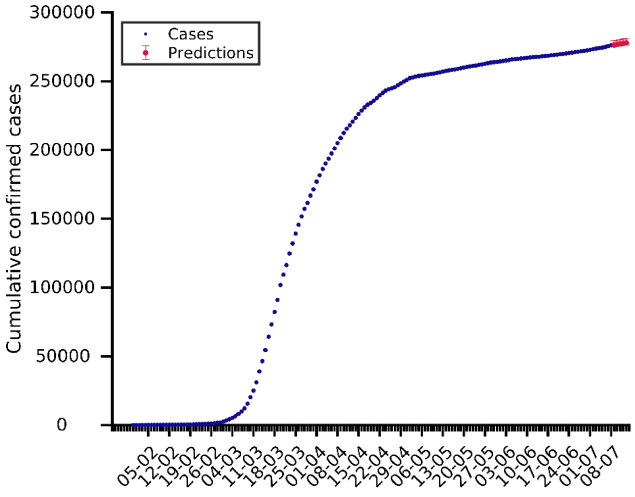


(3) Analysis and prediction of COVID-19 for Spain and its autonomous communities

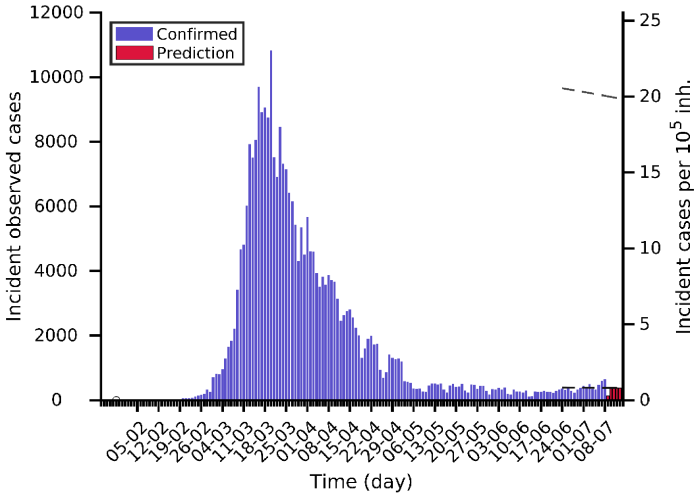
Data updated on 14th July, data series built with the day of the symptoms' onset, reliable until 6th July.

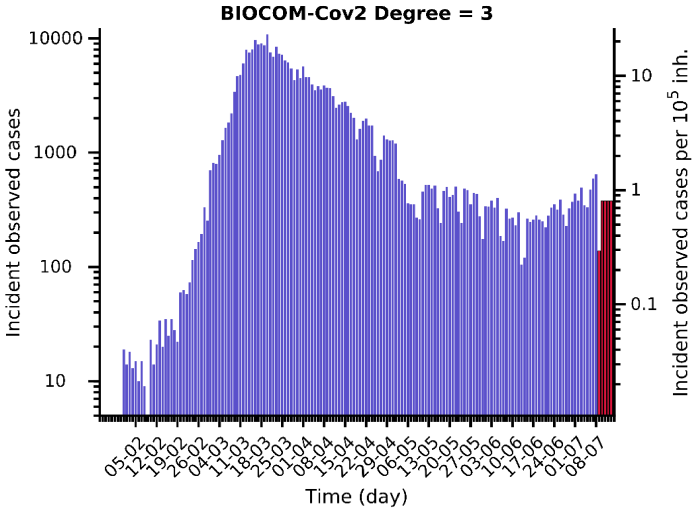
Data obtained from https://github.com/datadista/datasets/tree/master/COVID%2019 and https://covid19.isciii.es/

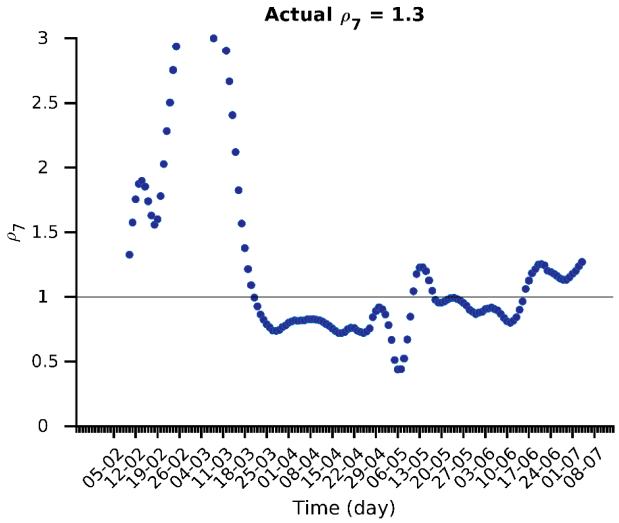
Spain 08-07-2020. Pop: 47.0M. Cumulative incidence: 587/10⁵



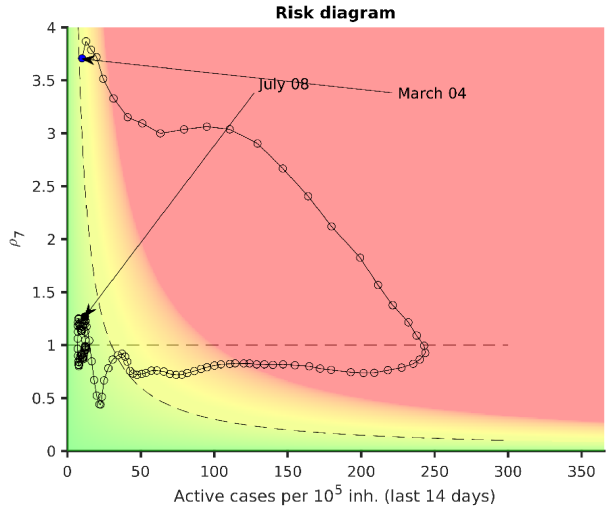
Deaths series currently under revision

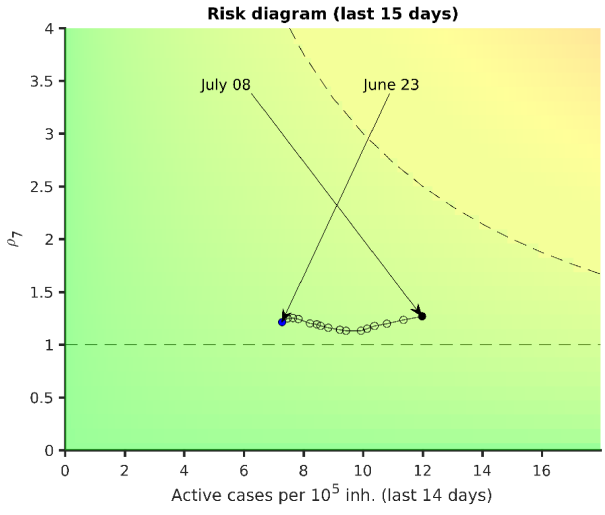




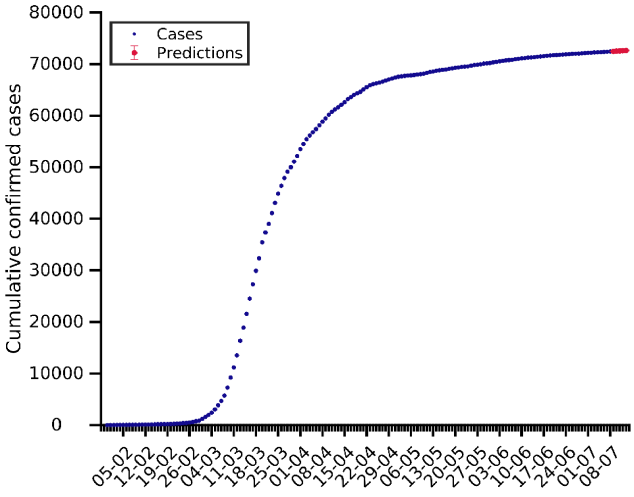


Deaths series currently under revision

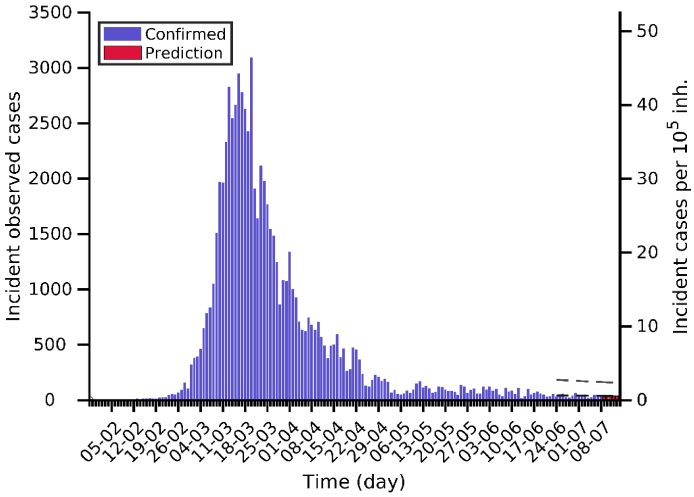


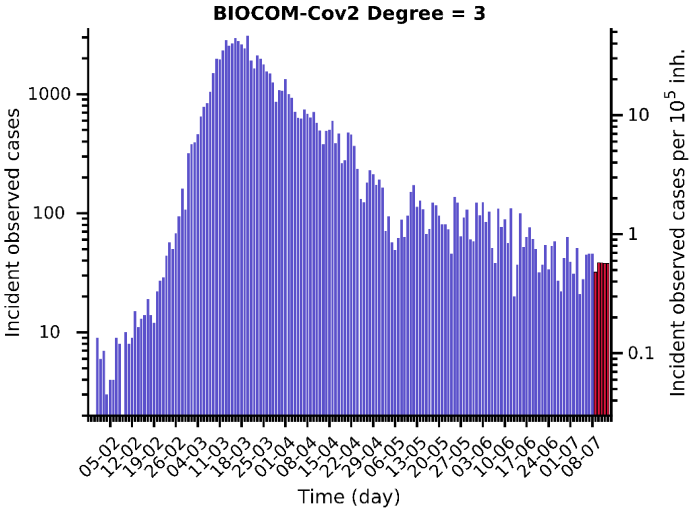


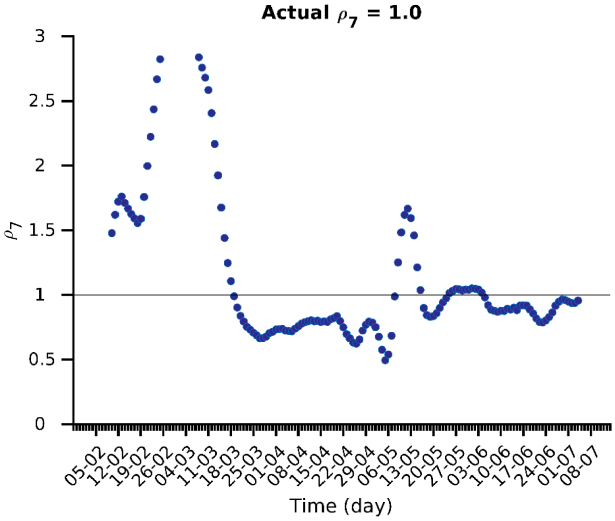
Madrid 08-07-2020. Pop: 6.7M. Cumulative incidence: 1087/10⁵



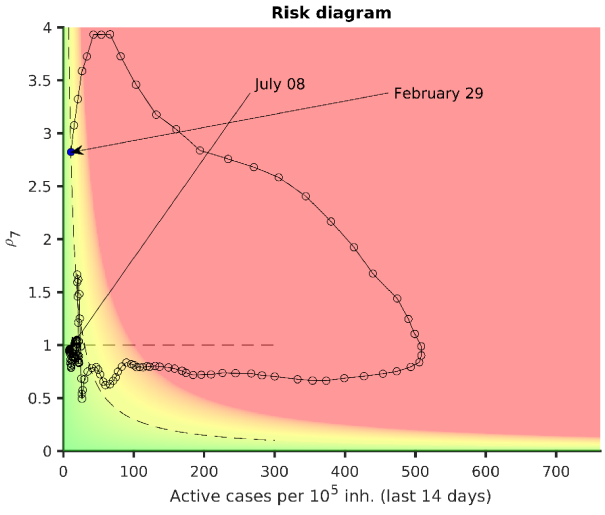
Deaths series currently under revision

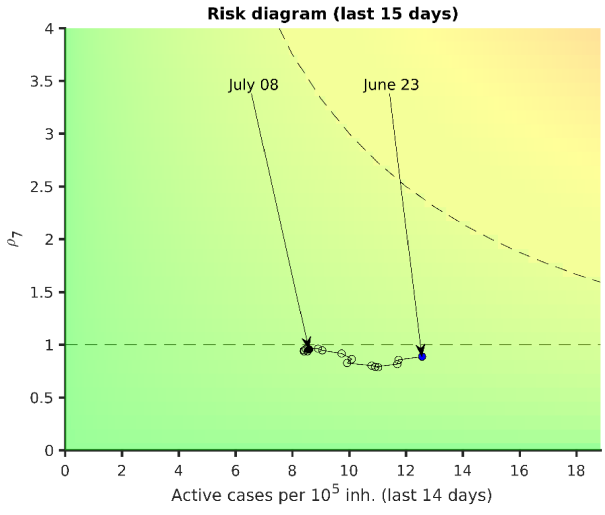




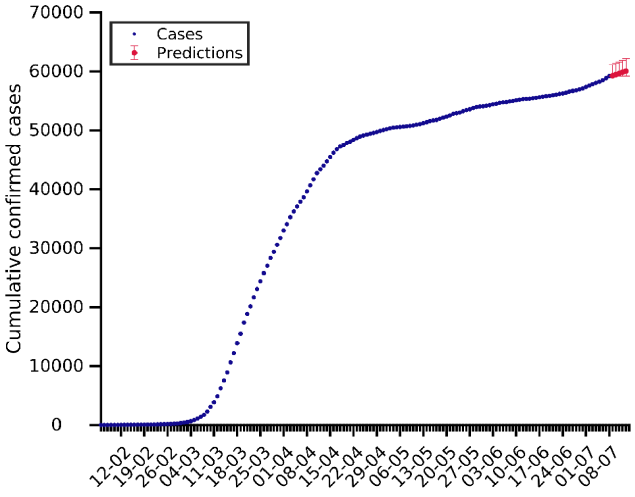


Deaths series currently under revision

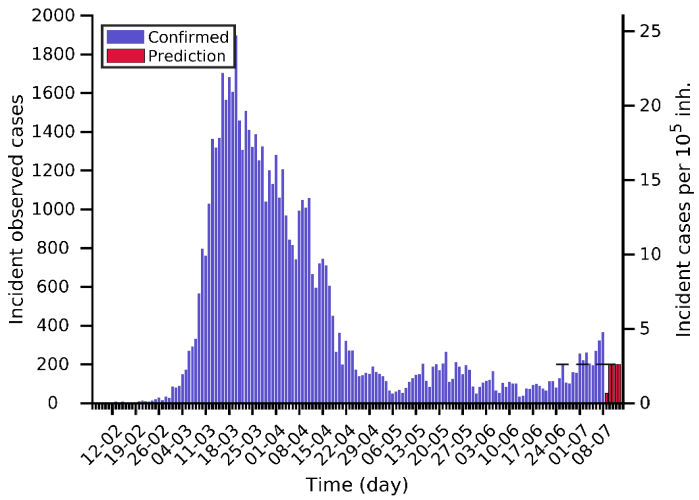


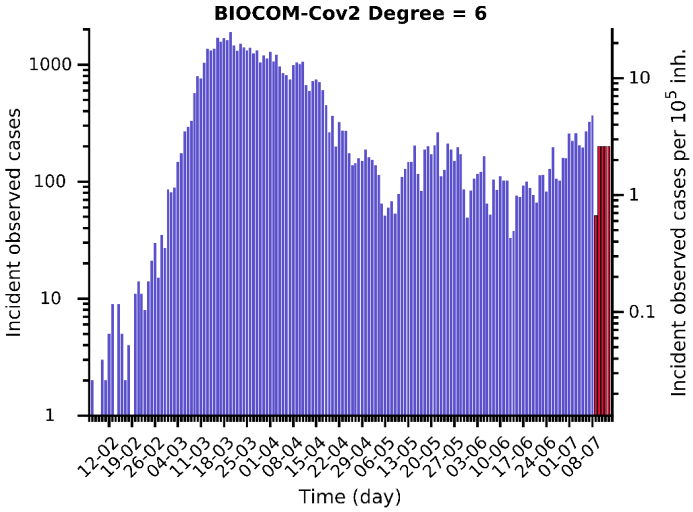


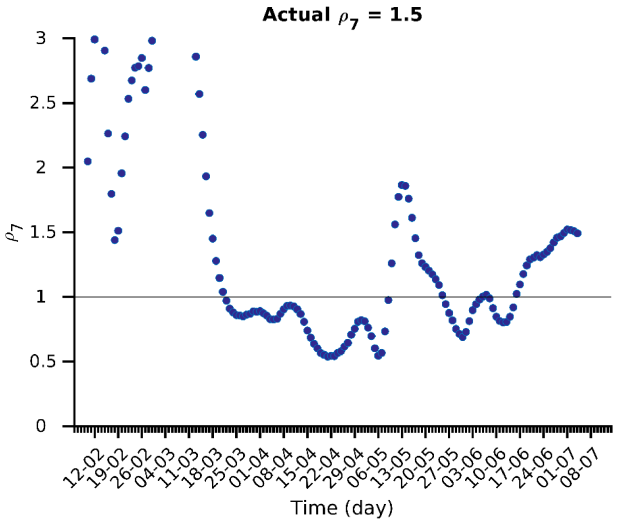
Catalunya 08-07-2020. Pop: 7.7M. Cumulative incidence: 771/10⁵



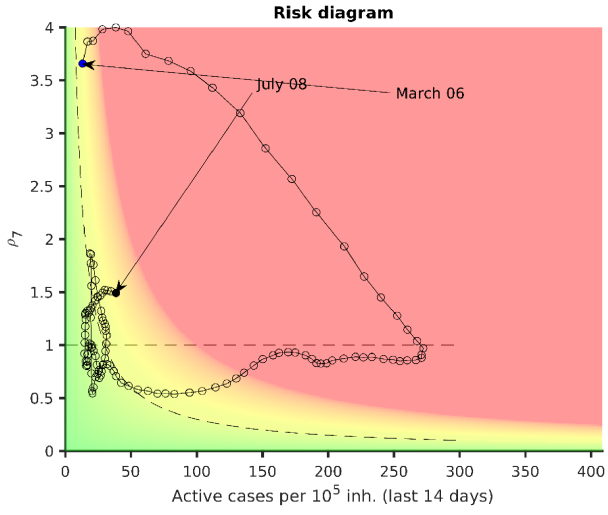
Deaths series currently under revision

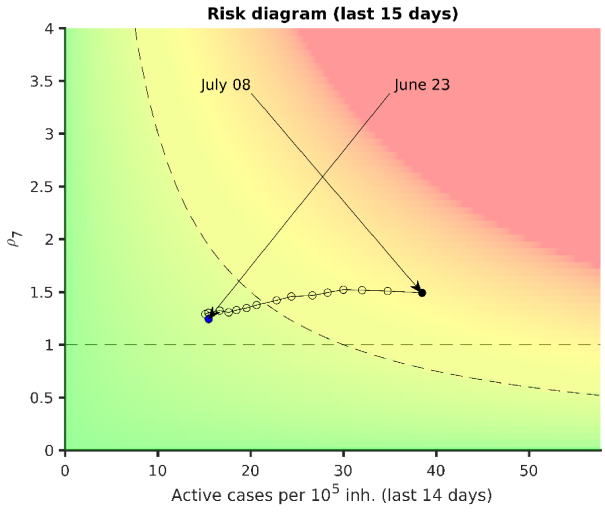




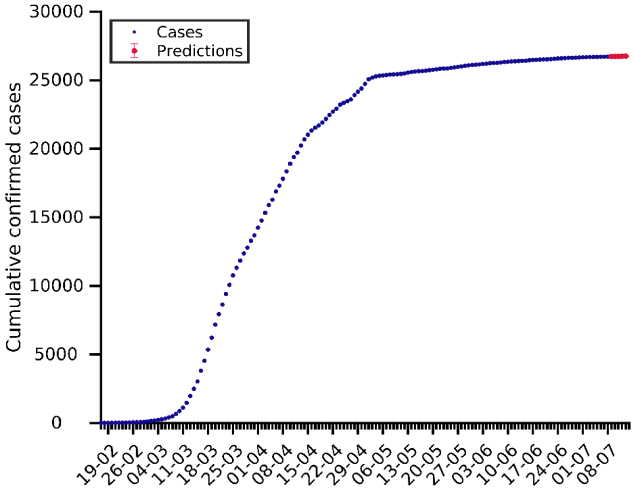


Deaths series currently under revision

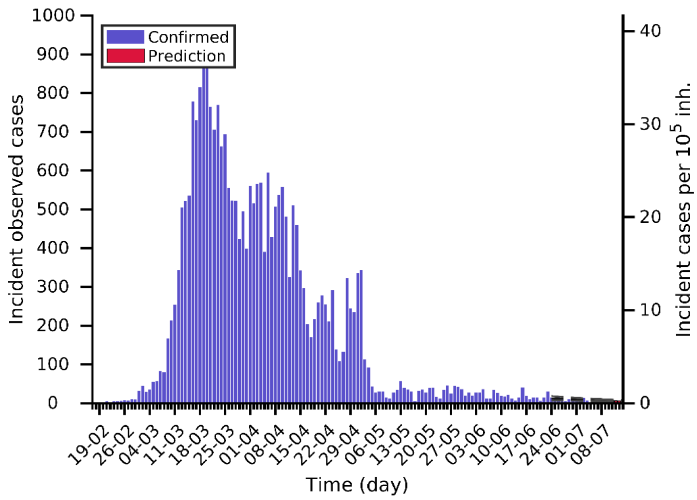


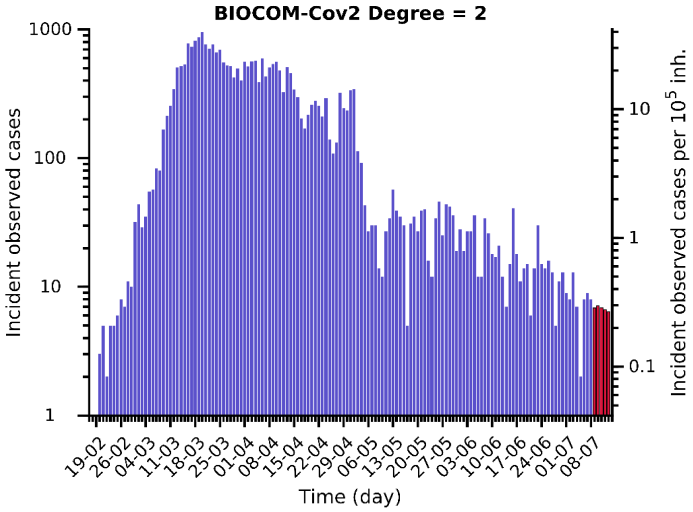


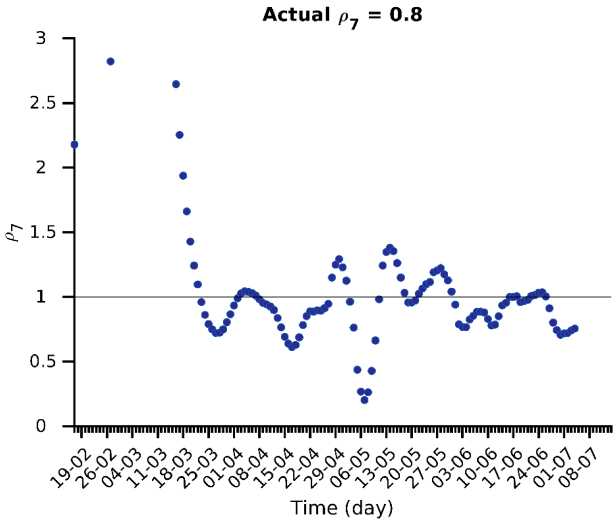
Castilla Leon 08-07-2020. Pop: 2.4M. Cumulative incidence: 1114/10⁵



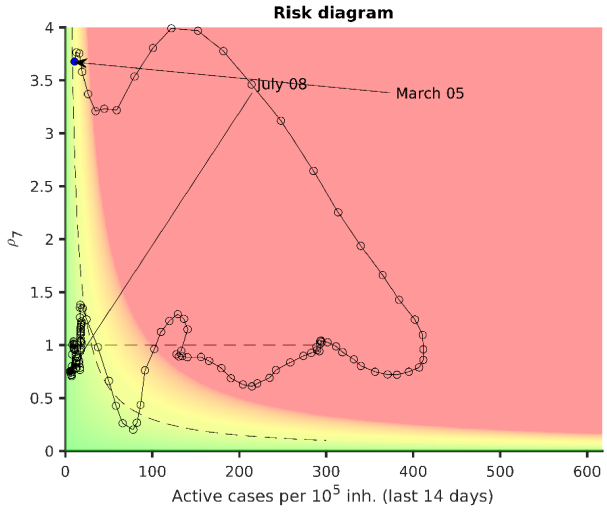
Deaths series currently under revision

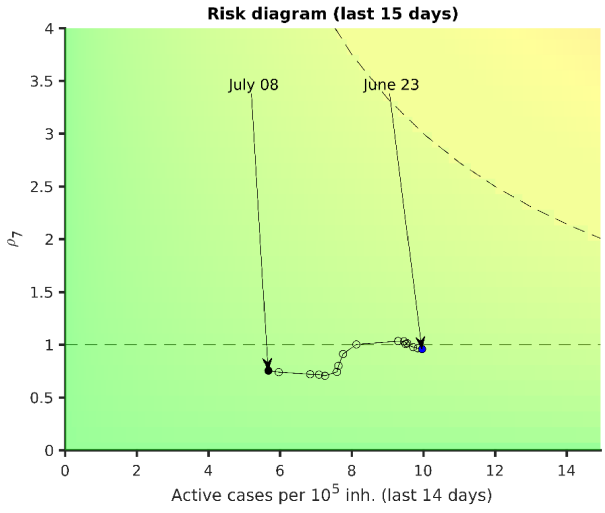




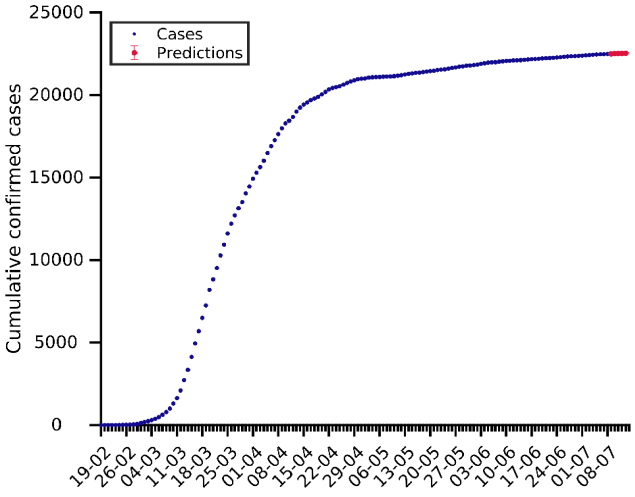


Deaths series currently under revision

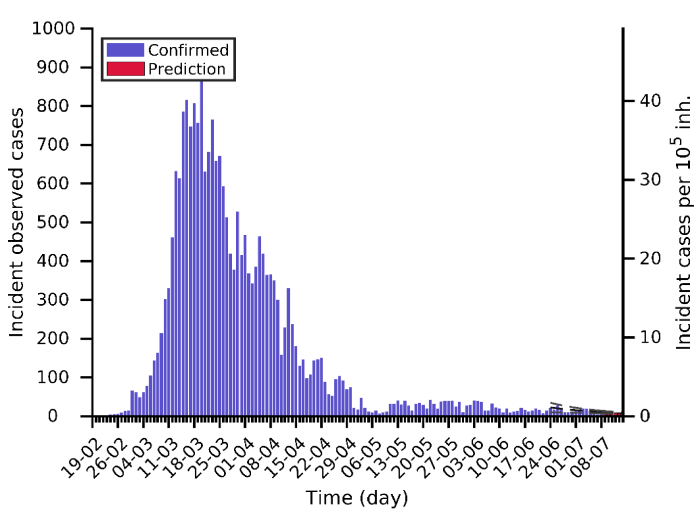


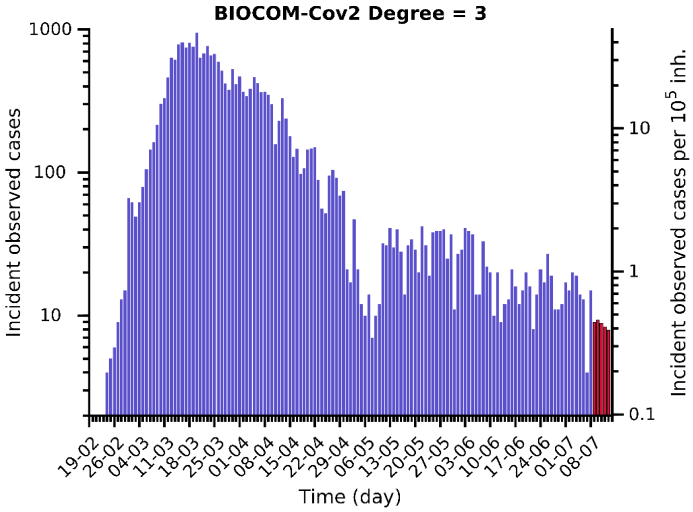


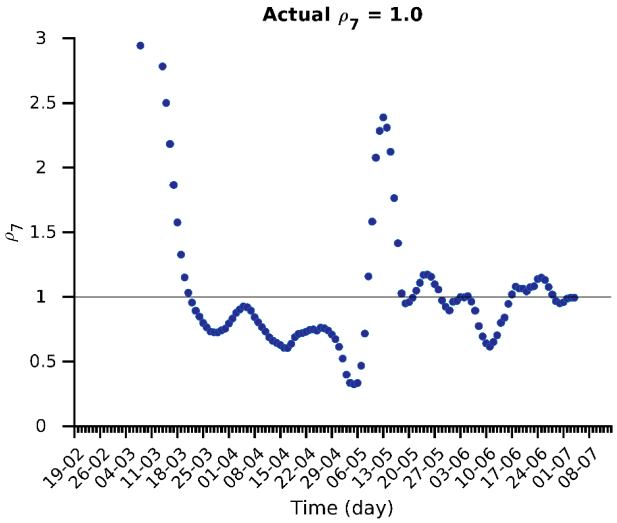
Castilla-La Mancha 08-07-2020. Pop: 2.0M. Cumulative incidence: 1106/10^5



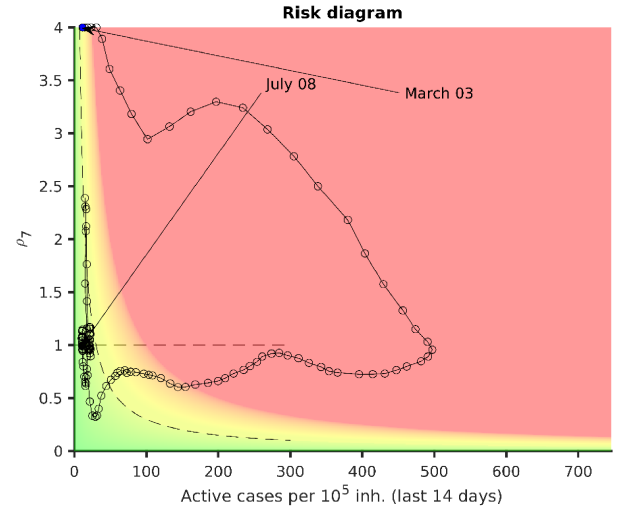
Deaths series currently under revision

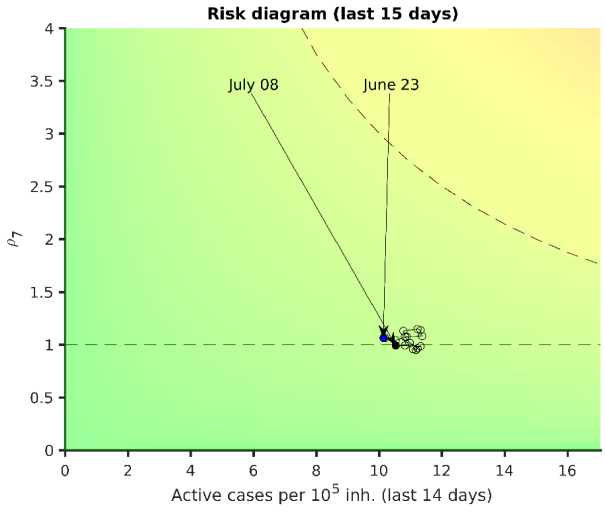




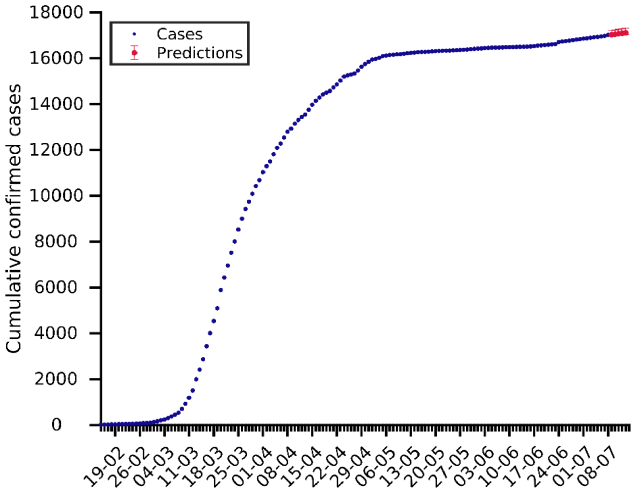


Deaths series currently under revision

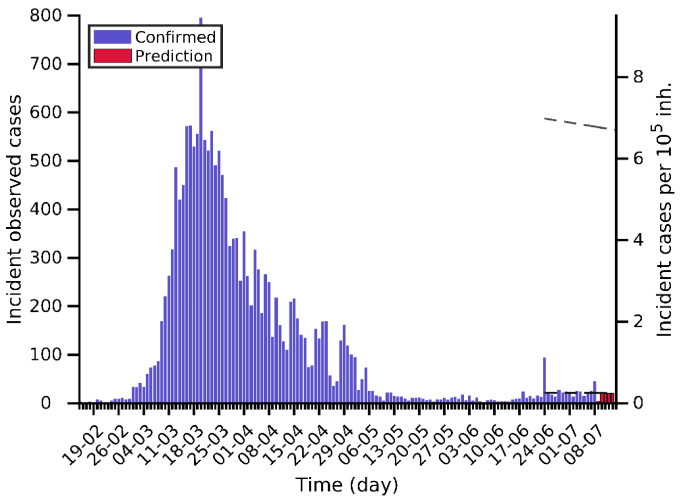


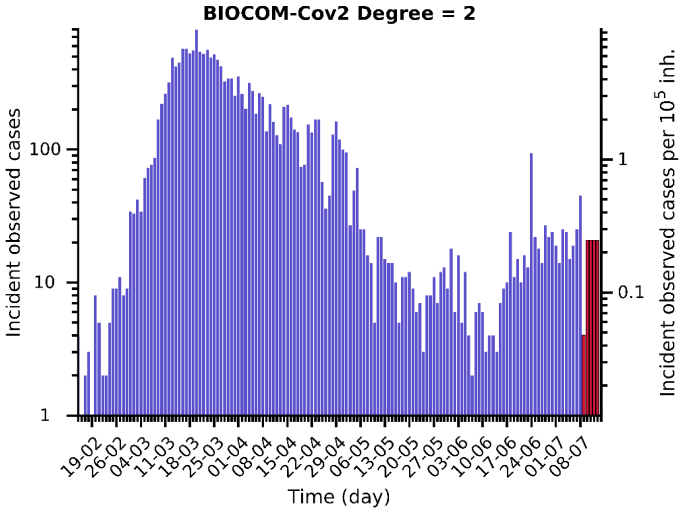


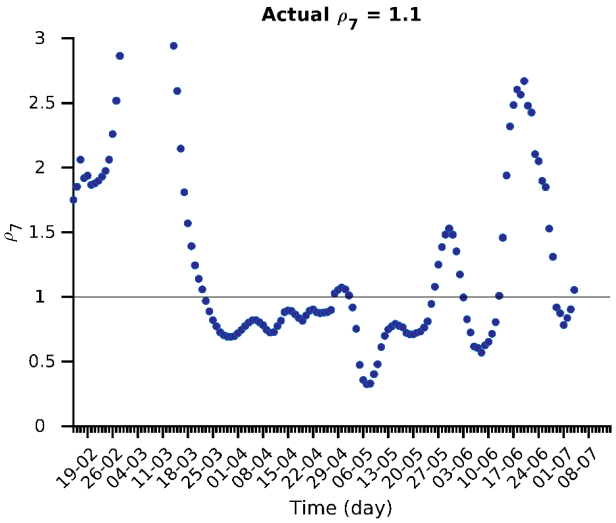
Andalucia 08-07-2020. Pop: 8.4M. Cumulative incidence: 202/10^5



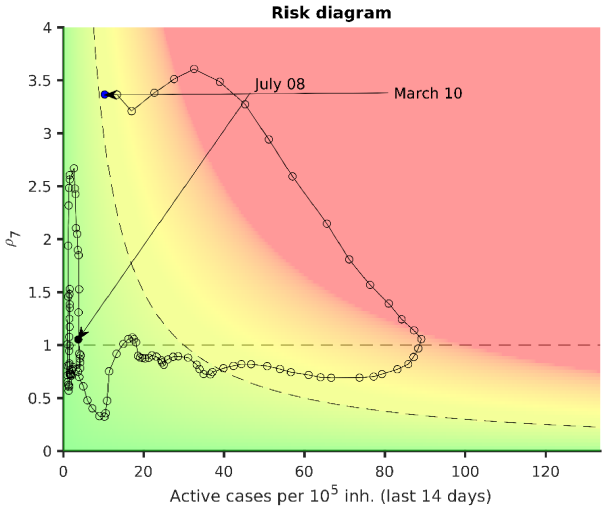
Deaths series currently under revision

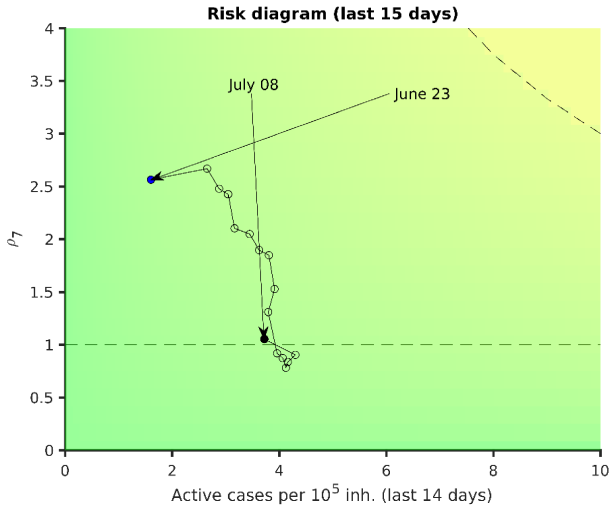




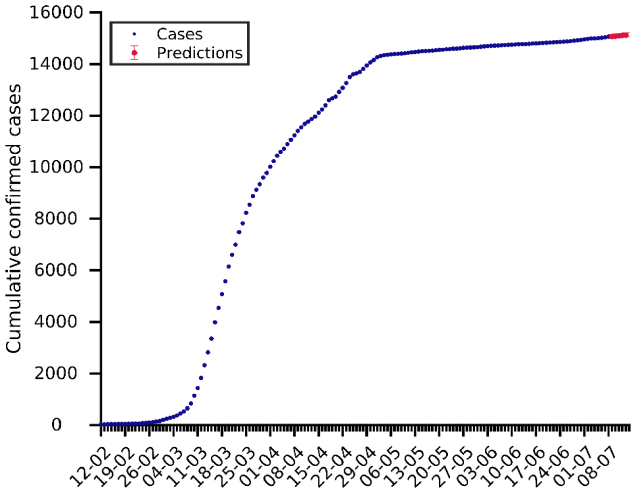


Deaths series currently under revision

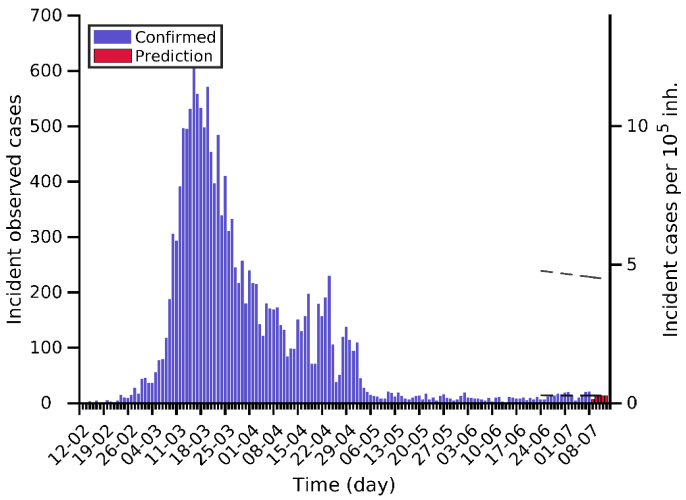


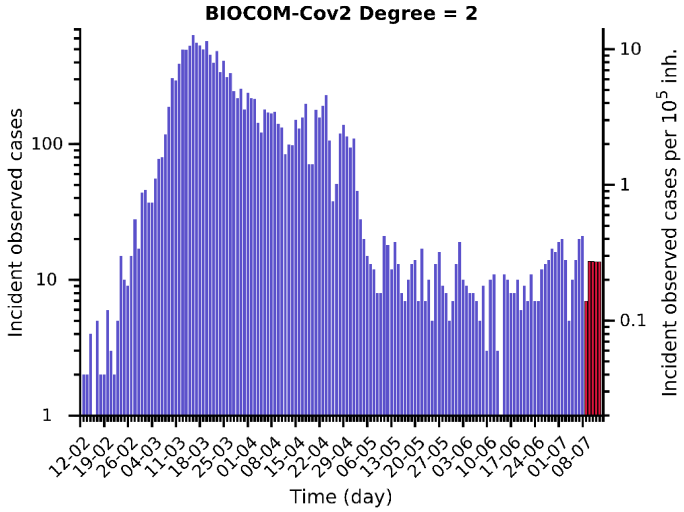


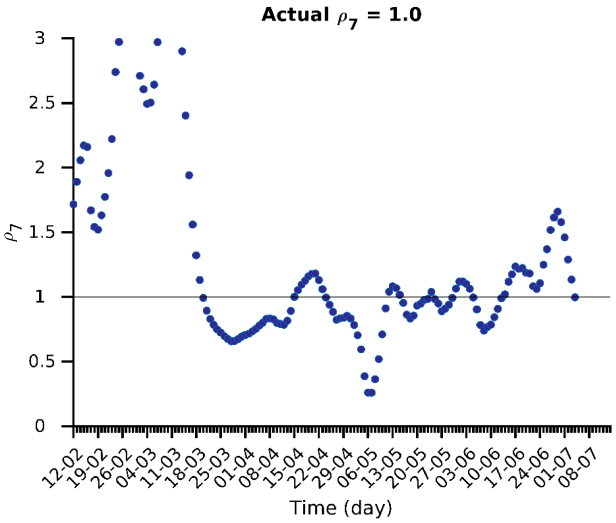
C Valenciana 08-07-2020. Pop: 5.0M. Cumulative incidence: 301/10⁵



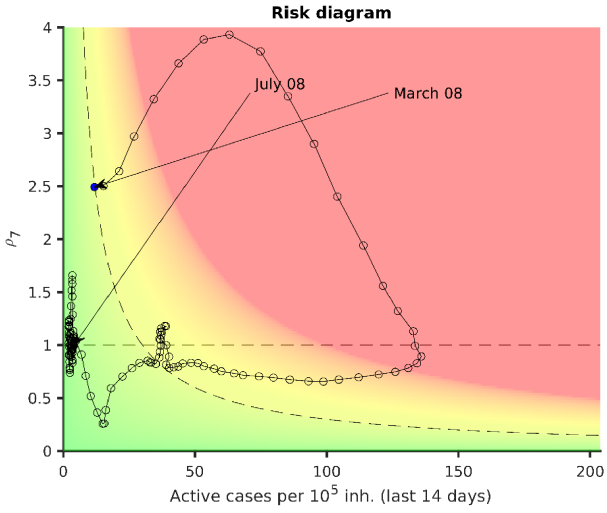
Deaths series currently under revision

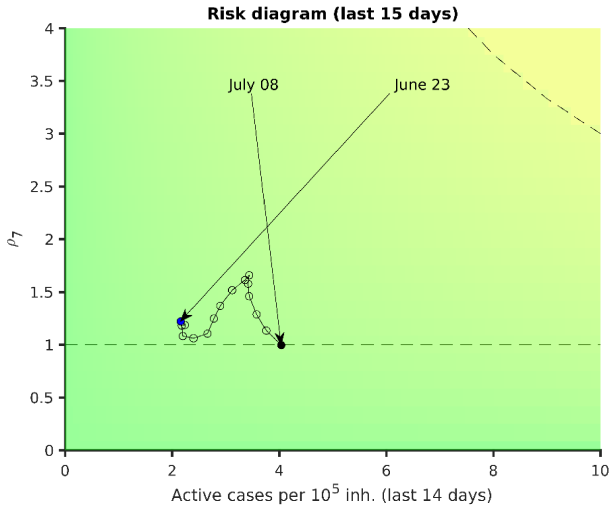




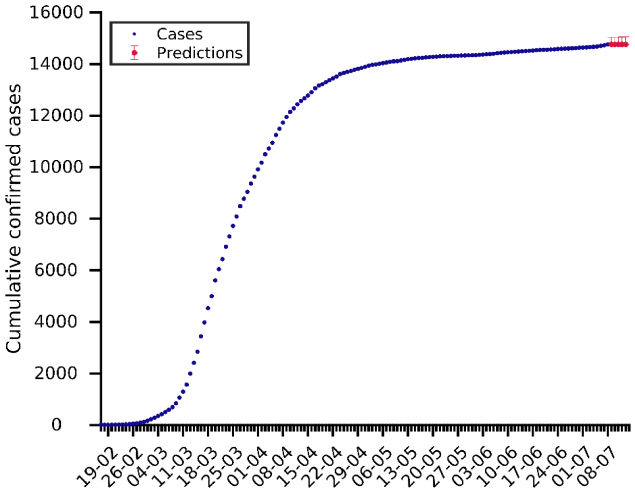


Deaths series currently under revision

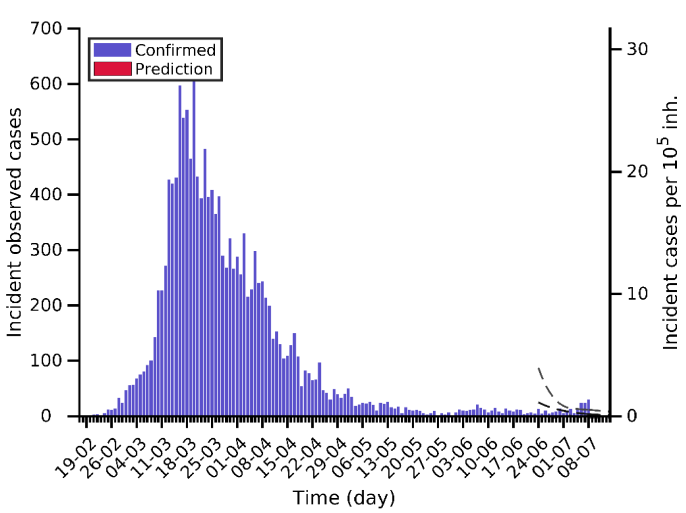


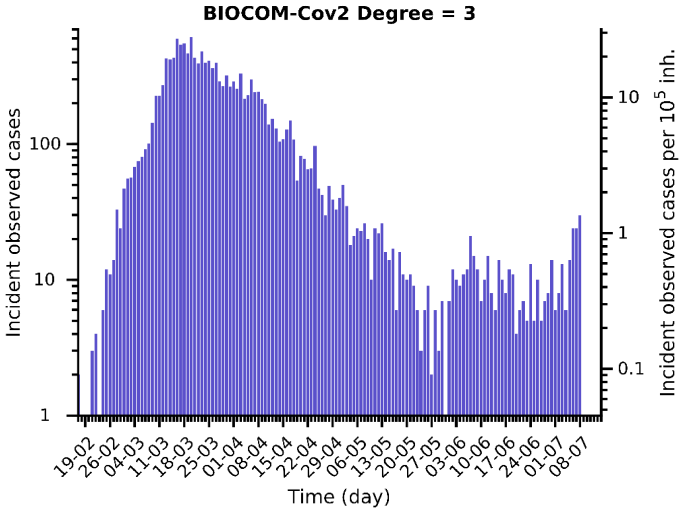


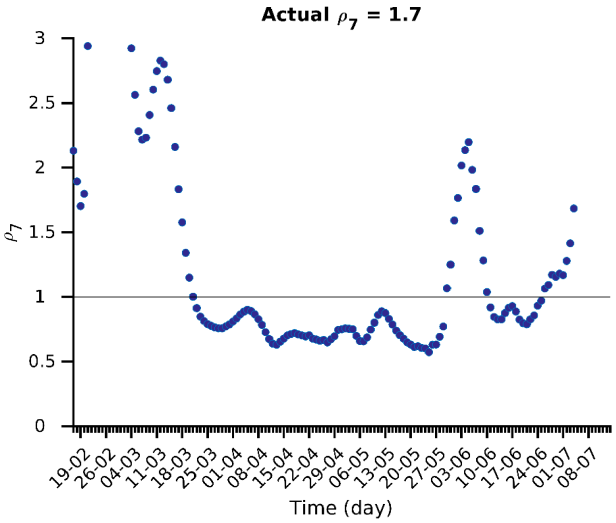
Euskadi 08-07-2020. Pop: 2.2M. Cumulative incidence: 668/10⁵



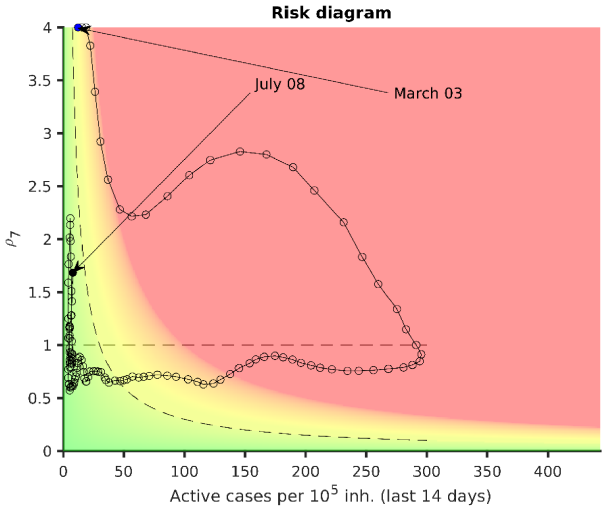
Deaths series currently under revision

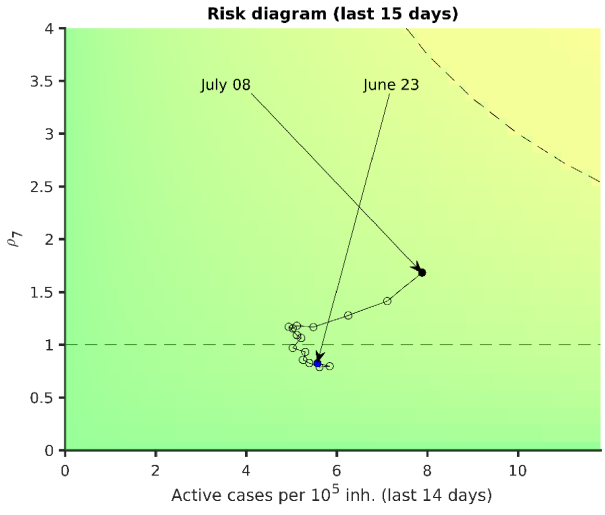




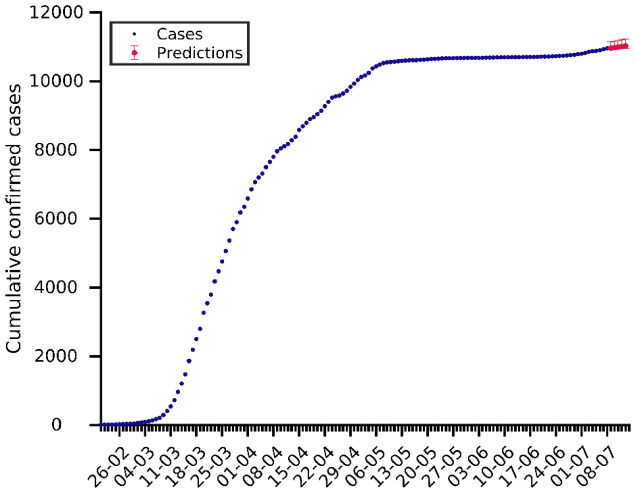


Deaths series currently under revision

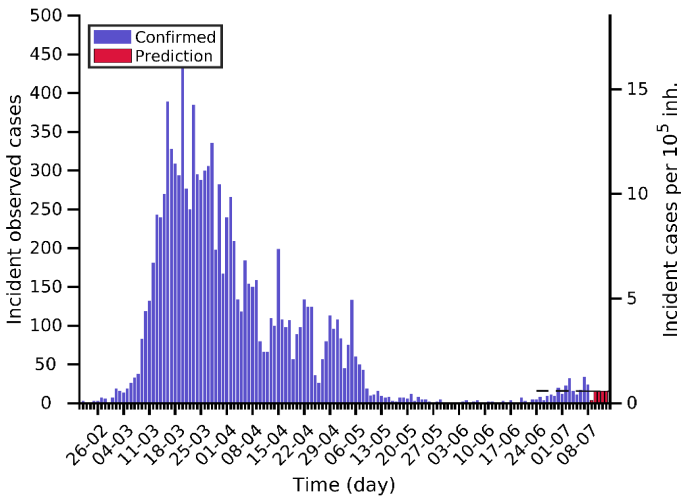


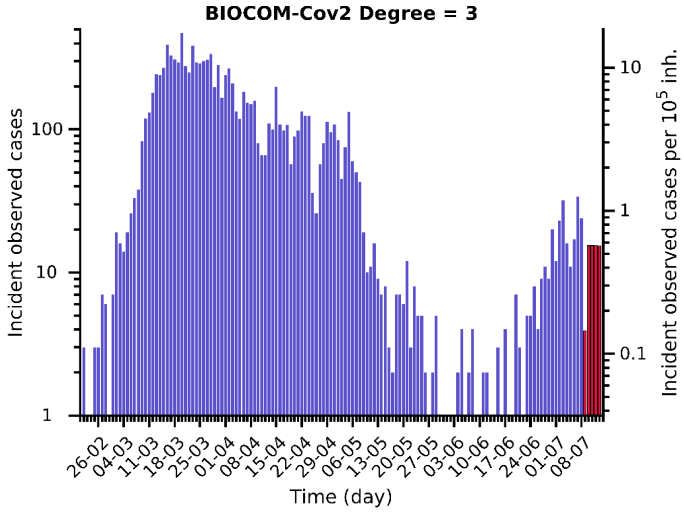


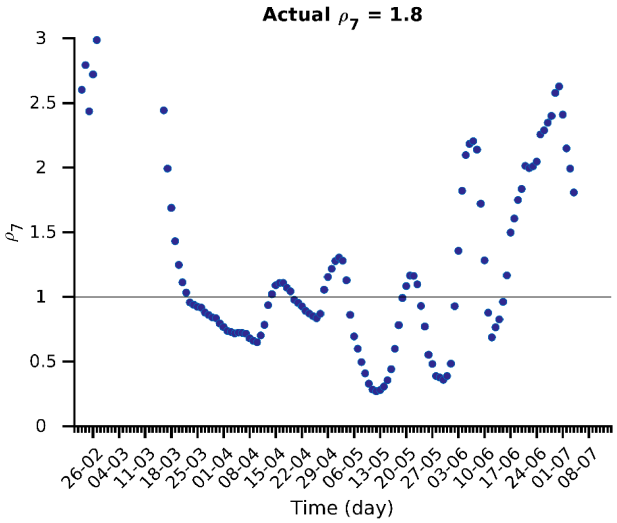
Galicia 08-07-2020. Pop: 2.7M. Cumulative incidence: 406/10⁵



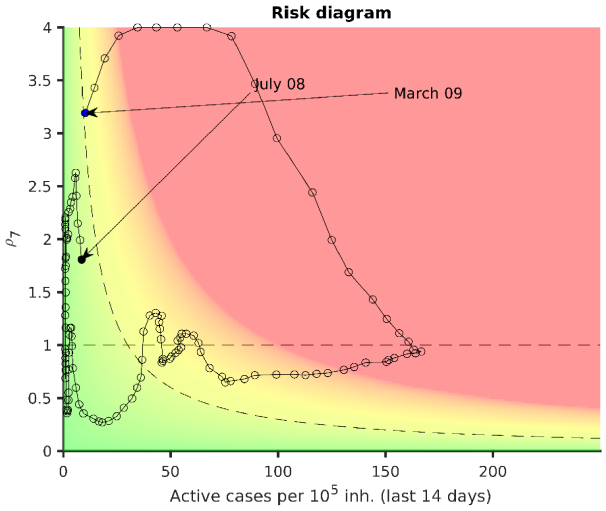
Deaths series currently under revision

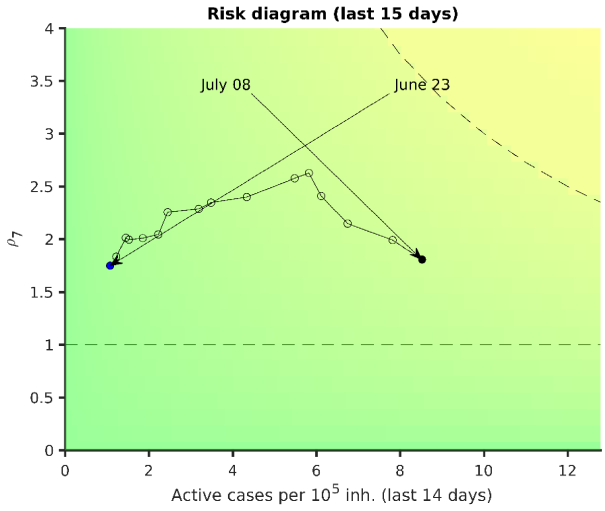




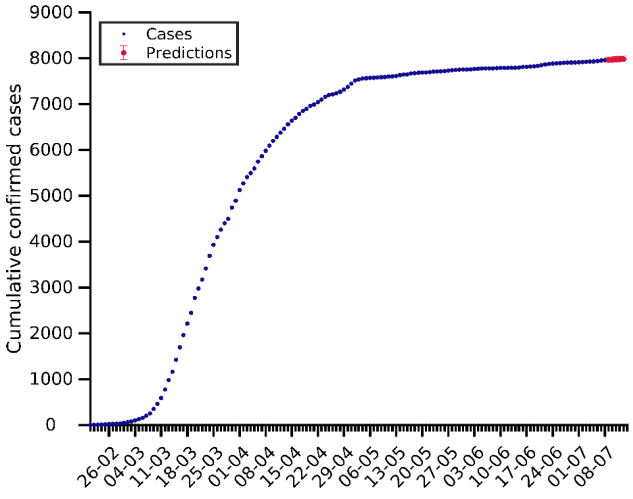


Deaths series currently under revision

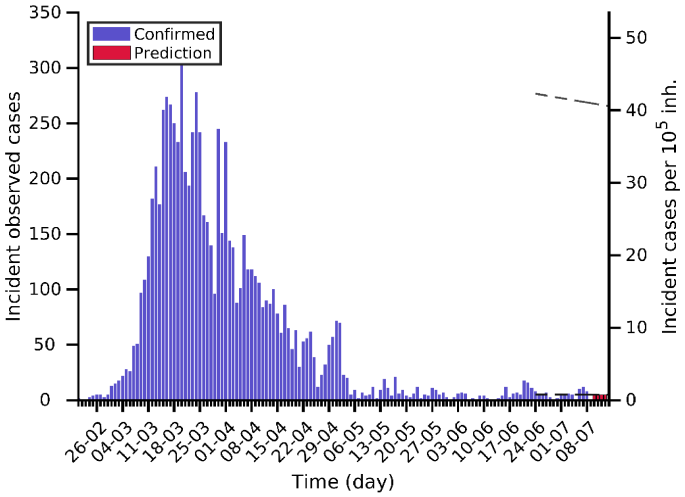


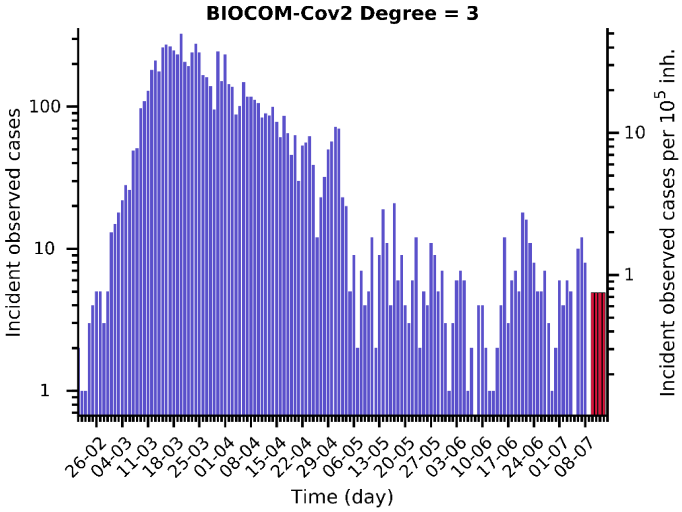


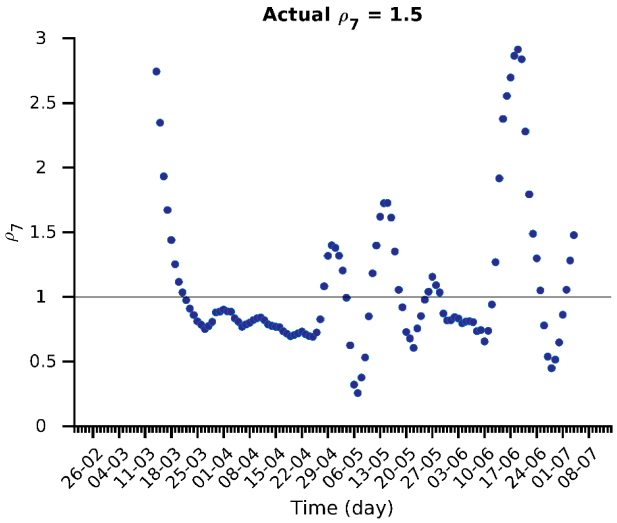
Navarra 08-07-2020. Pop: 0.7M. Cumulative incidence: $1217/10^5$



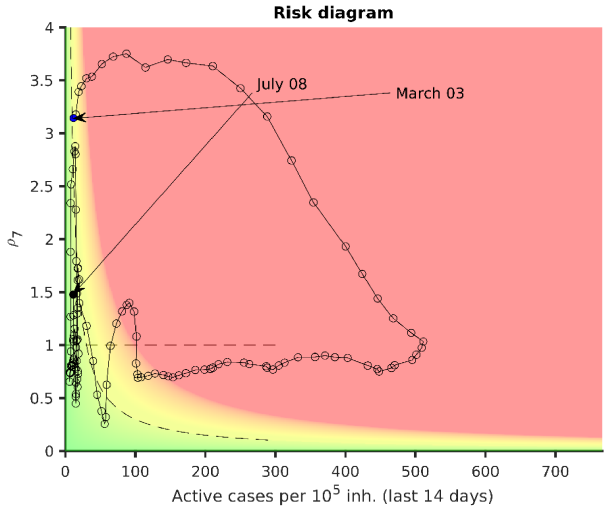
Deaths series currently under revision

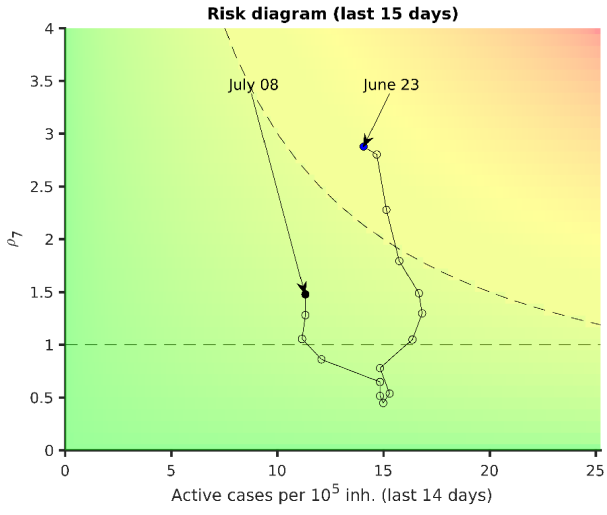




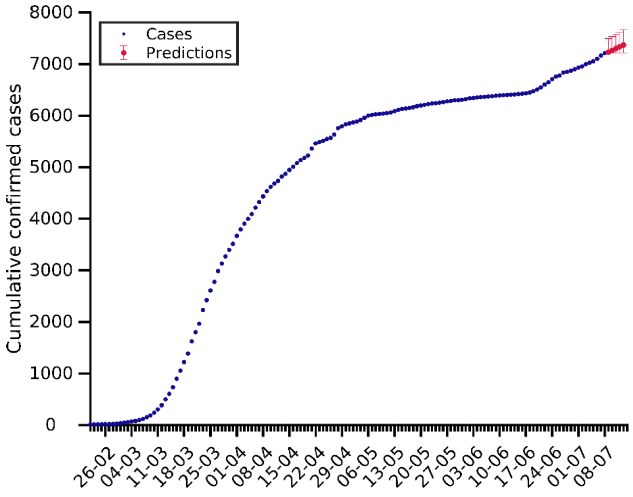


Deaths series currently under revision

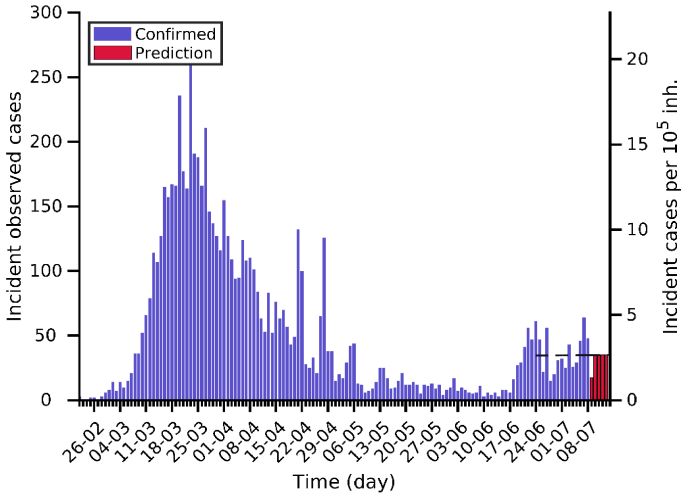


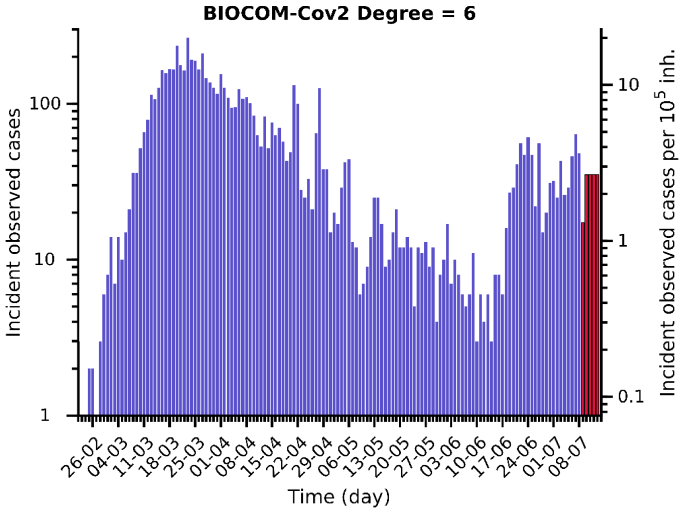


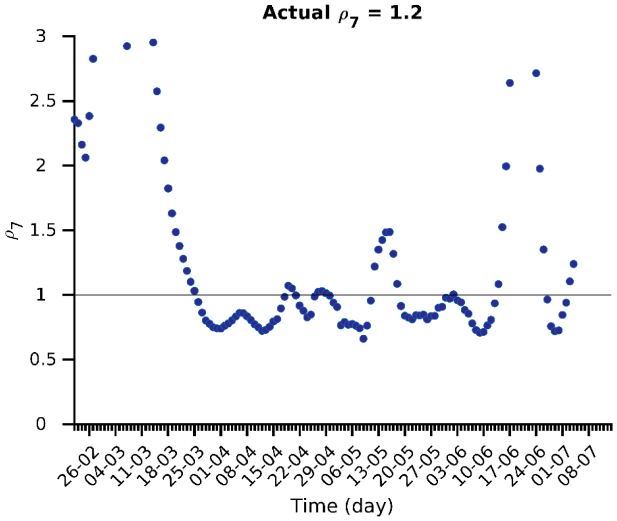
Aragon 08-07-2020. Pop: 1.3M. Cumulative incidence: 547/10⁵



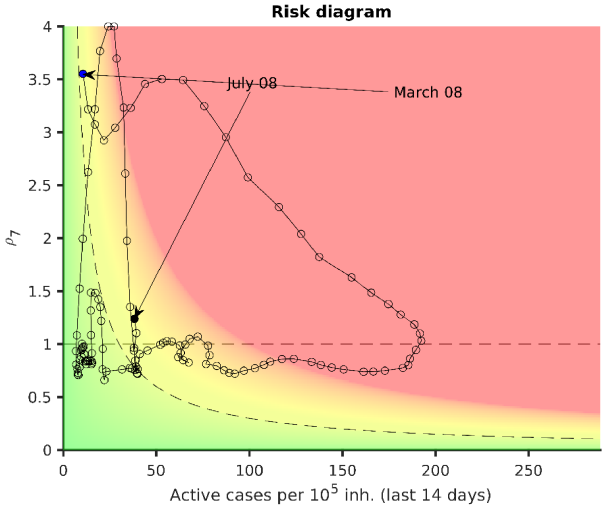
Deaths series currently under revision

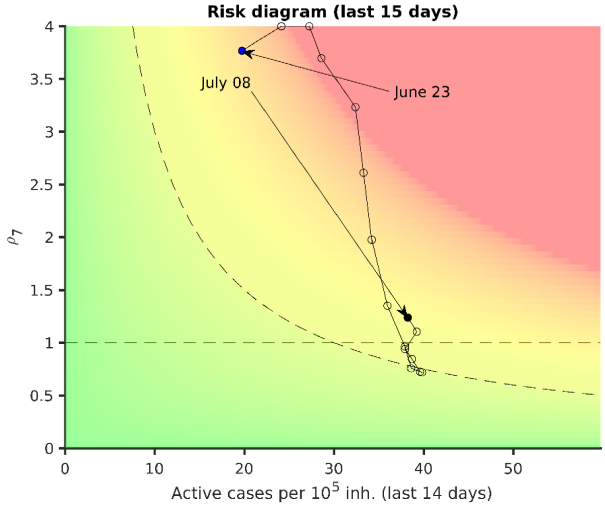




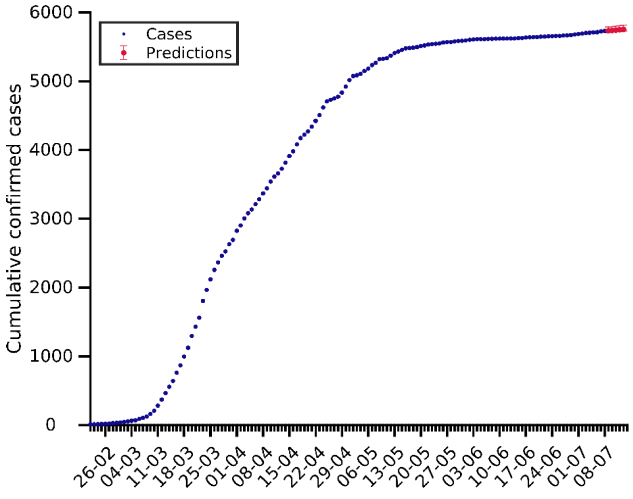


Deaths series currently under revision

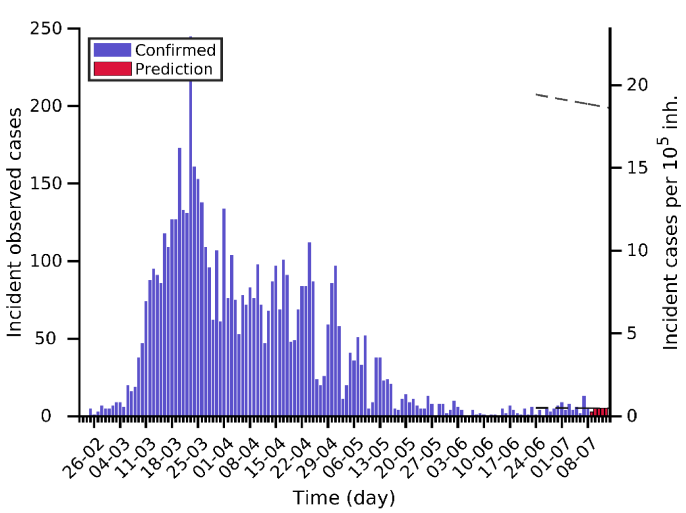


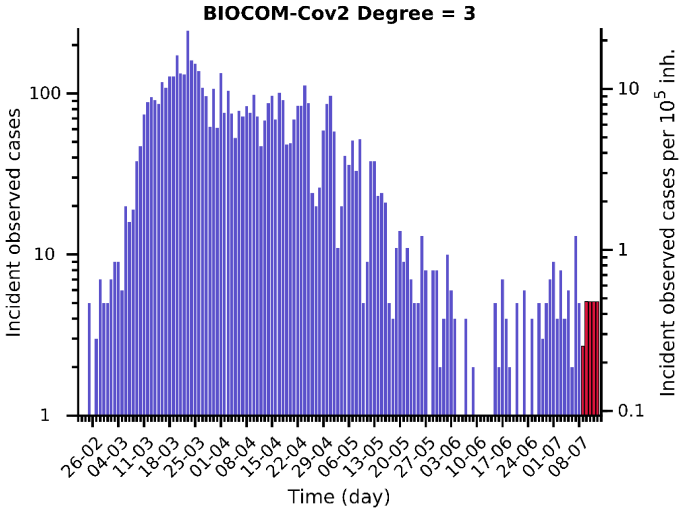


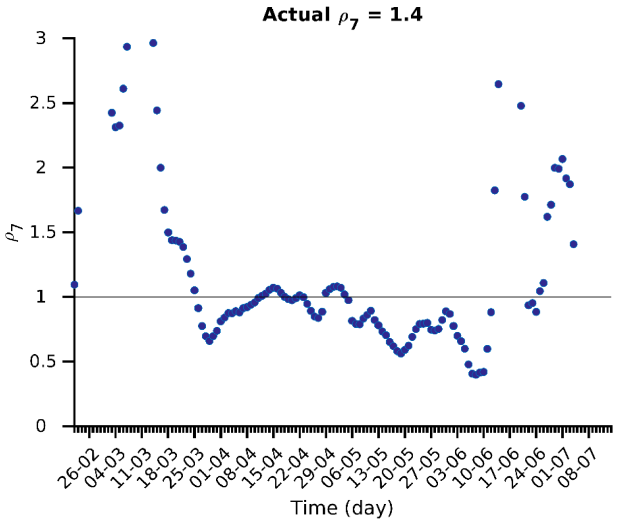
Extremadura 08-07-2020. Pop: 1.1M. Cumulative incidence: 537/10^5



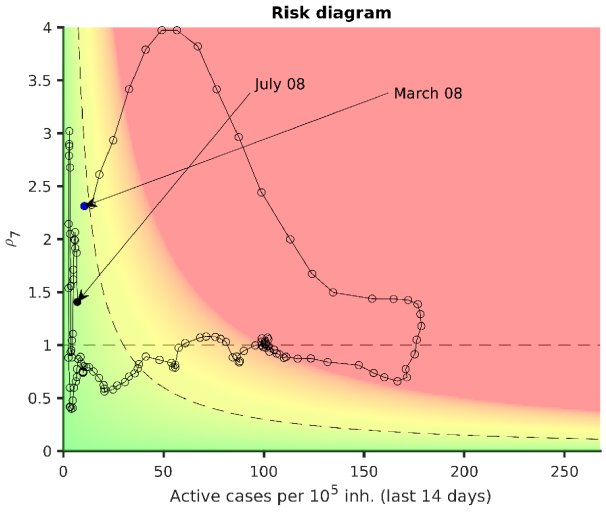
Deaths series currently under revision

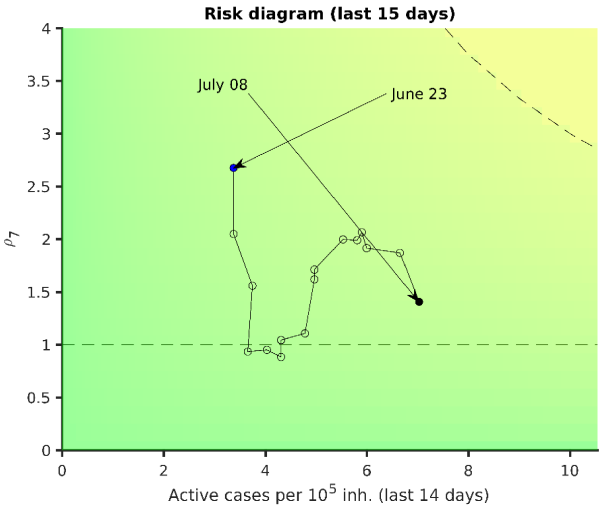




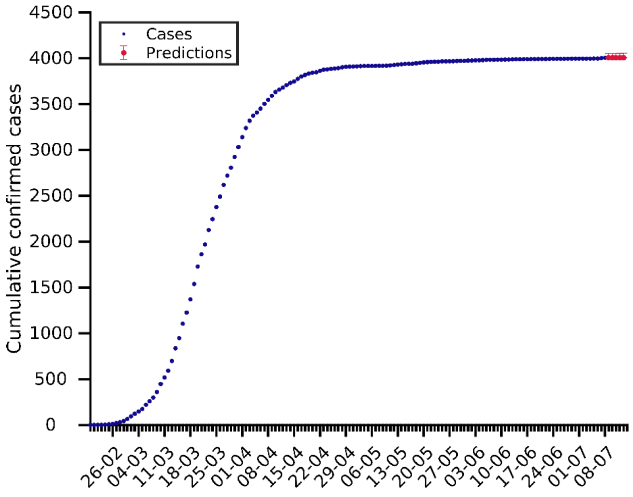


Deaths series currently under revision

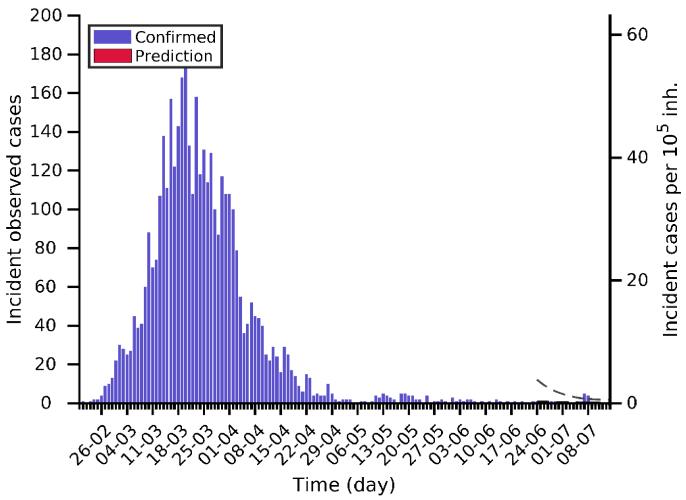


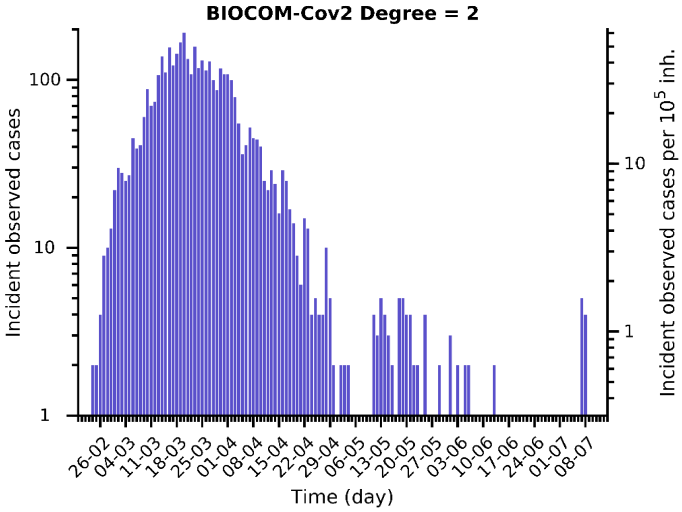


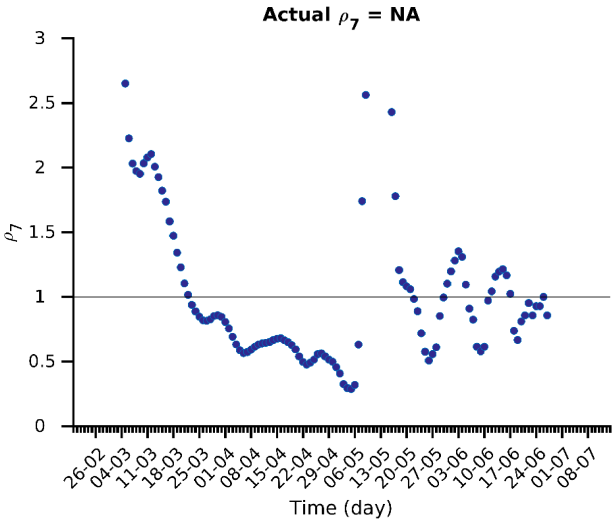
La Rioja 08-07-2020. Pop: 0.3M. Cumulative incidence: 1265/10⁵



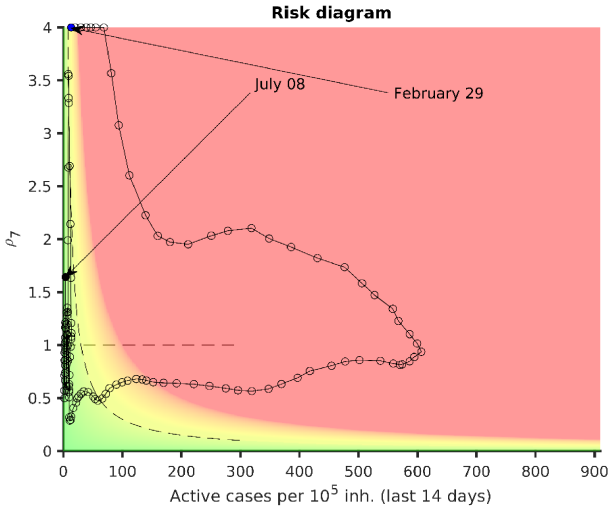
Deaths series currently under revision

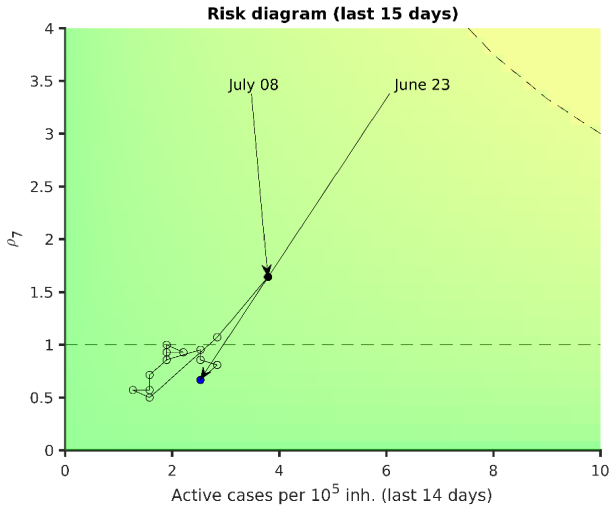




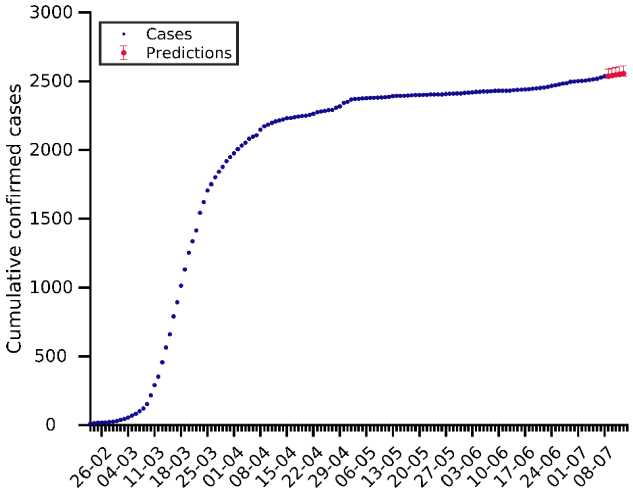


Deaths series currently under revision

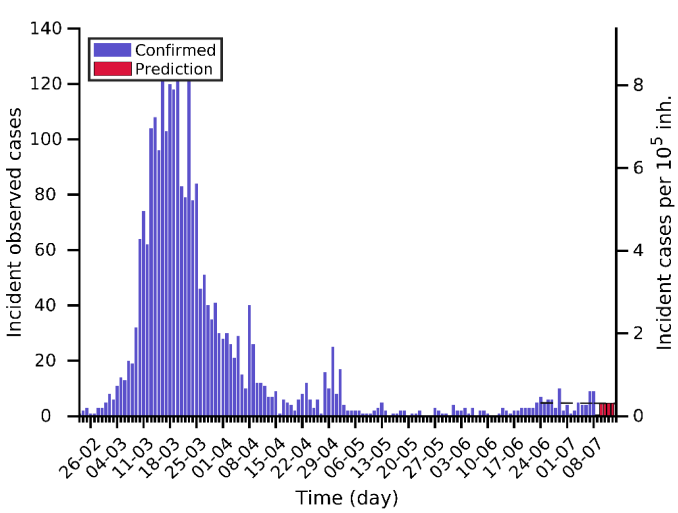


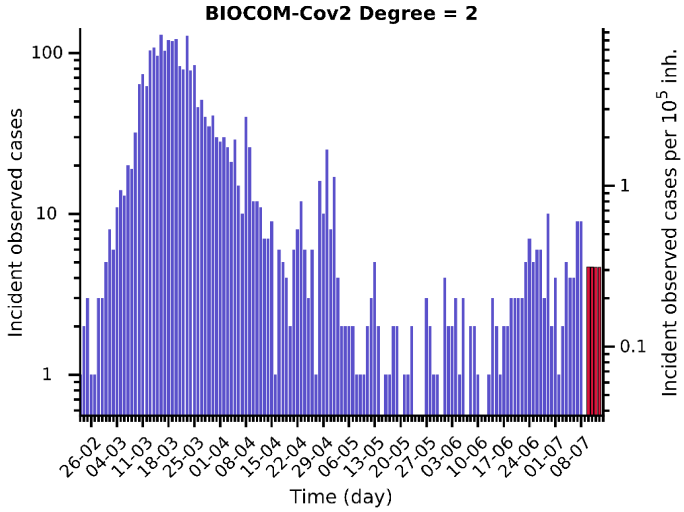


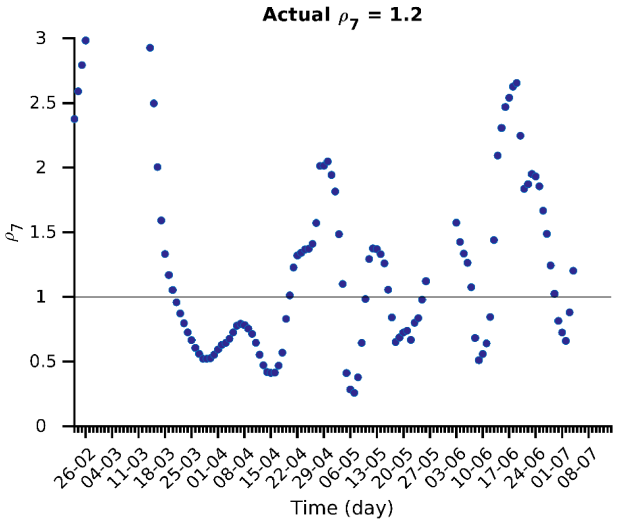
Murcia 08-07-2020. Pop: 1.5M. Cumulative incidence: 170/10⁵



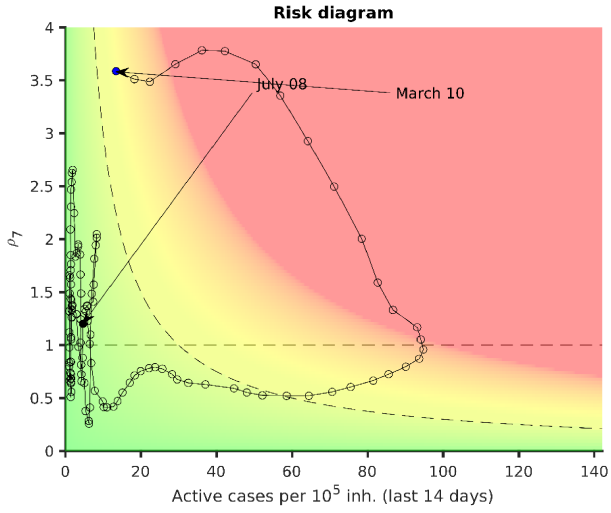
Deaths series currently under revision

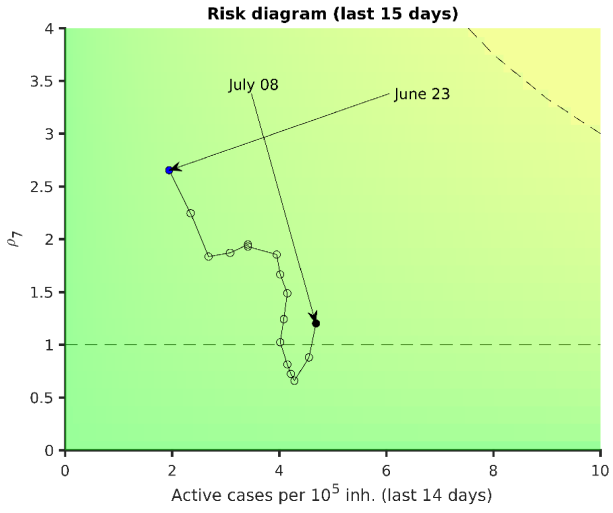




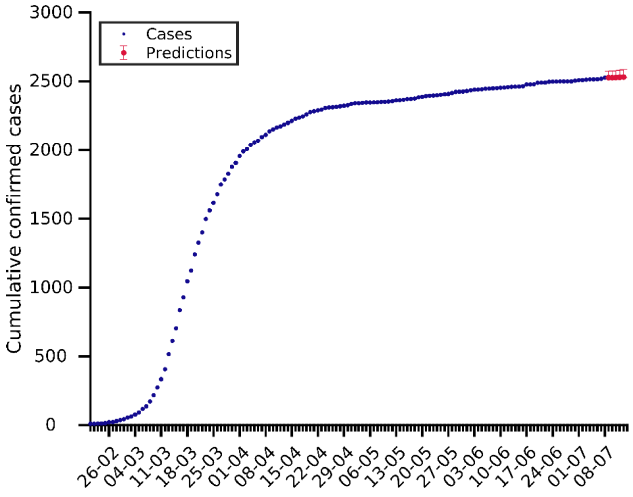


Deaths series currently under revision

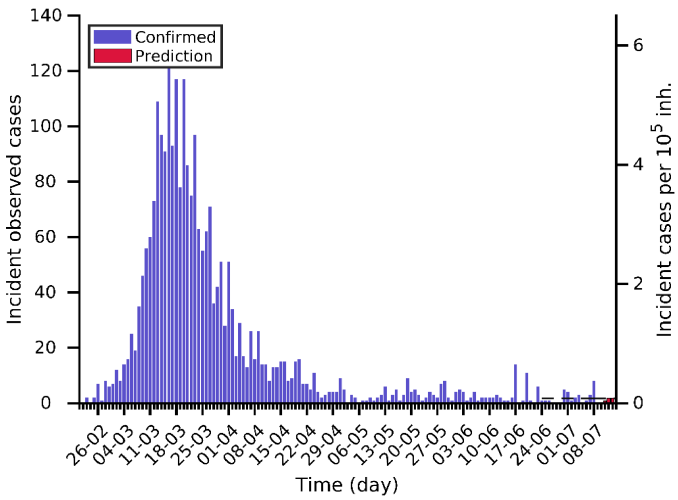


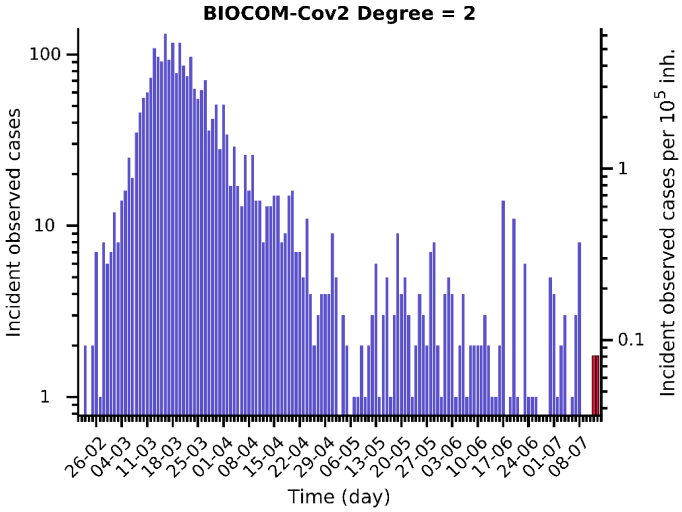


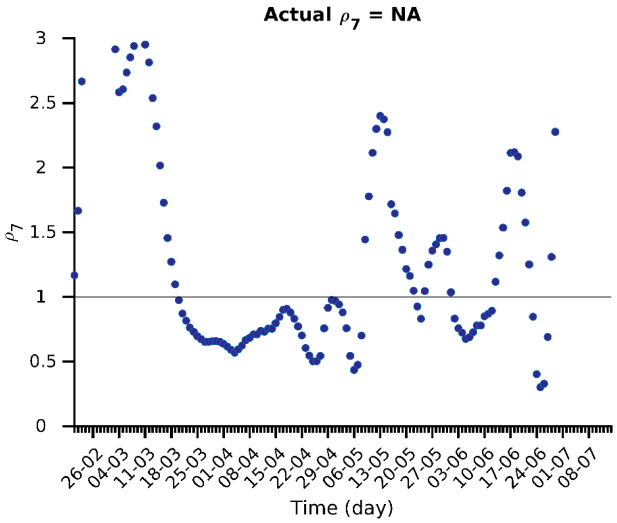
Canarias 08-07-2020. Pop: 2.2M. Cumulative incidence: 117/10⁵



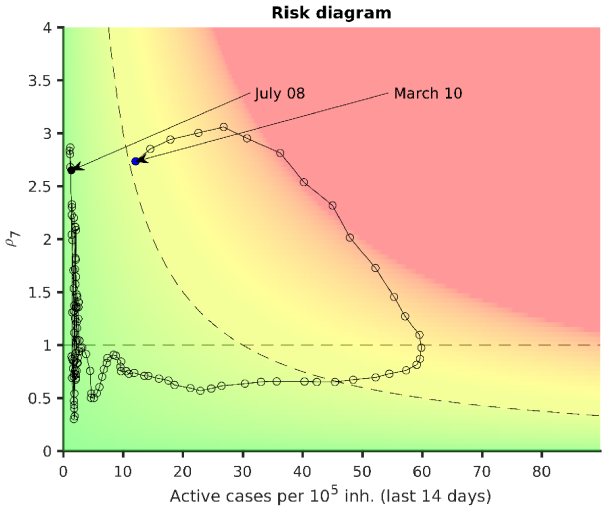
Deaths series currently under revision

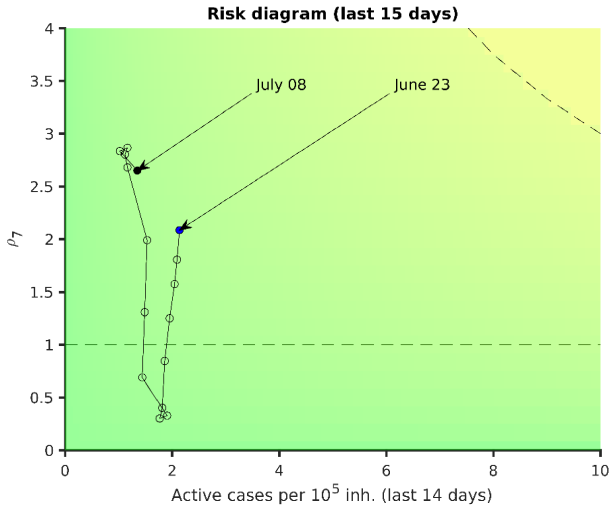




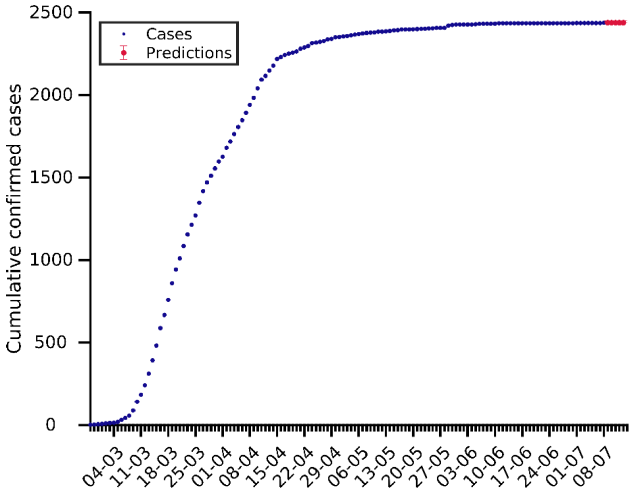


Deaths series currently under revision

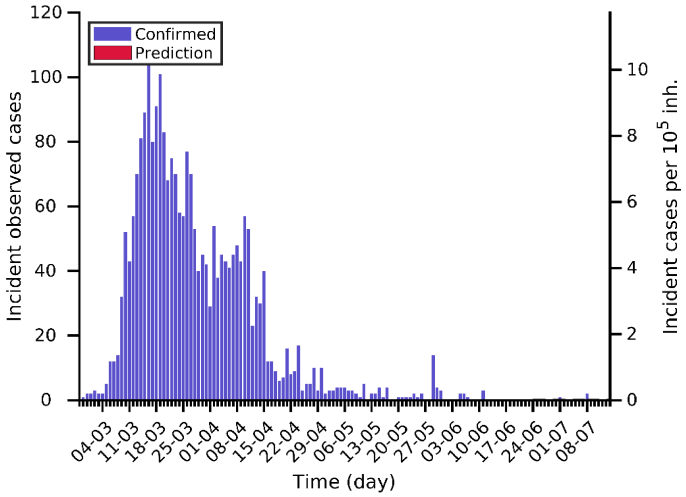


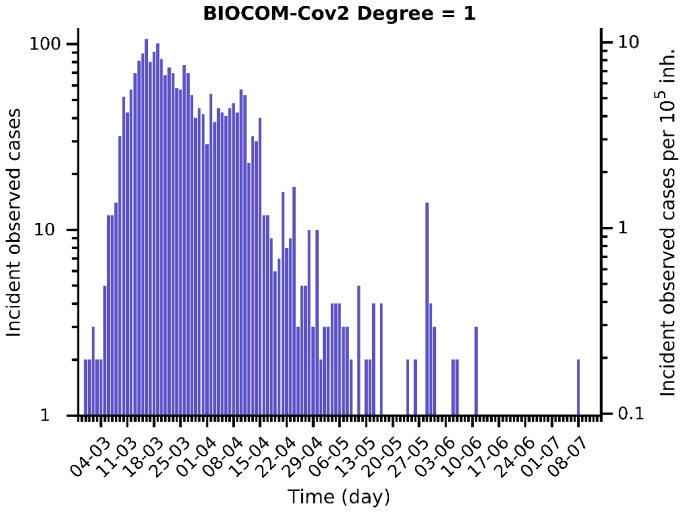


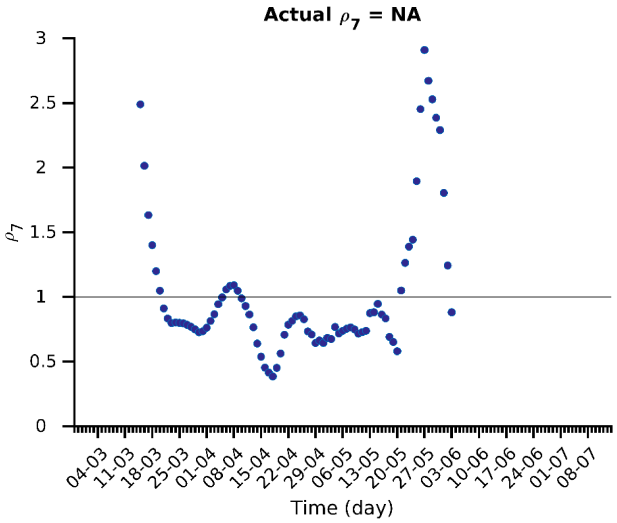
Asturias 08-07-2020. Pop: 1.0M. Cumulative incidence: 238/10⁵



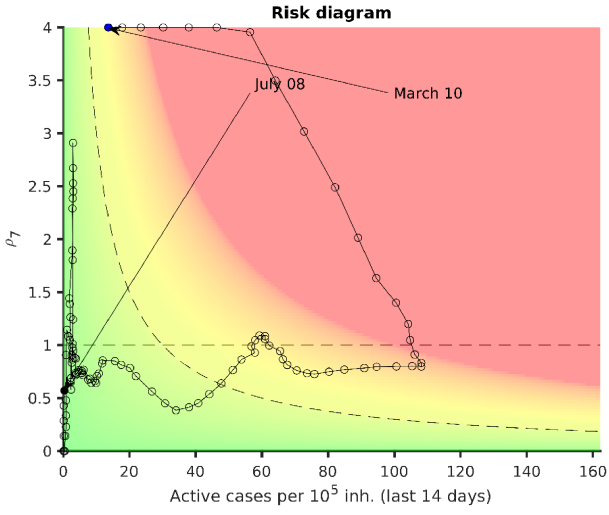
Deaths series currently under revision

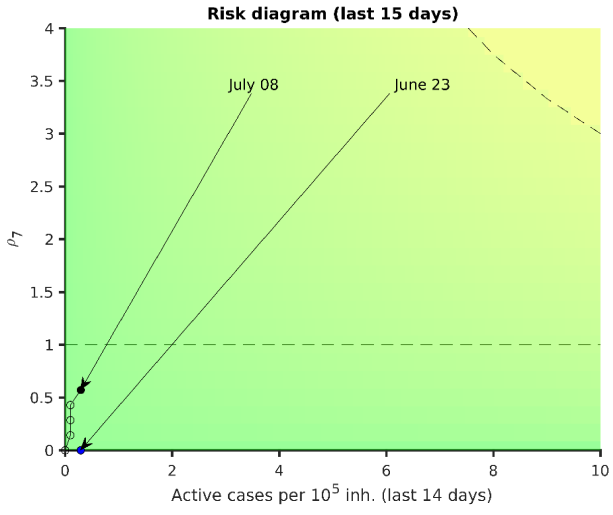




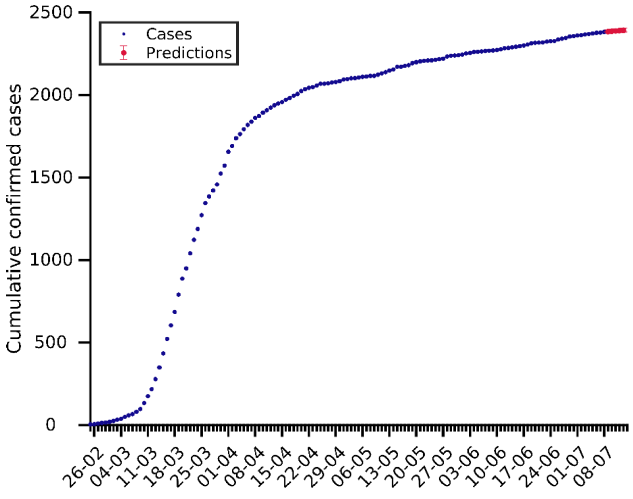


Deaths series currently under revision

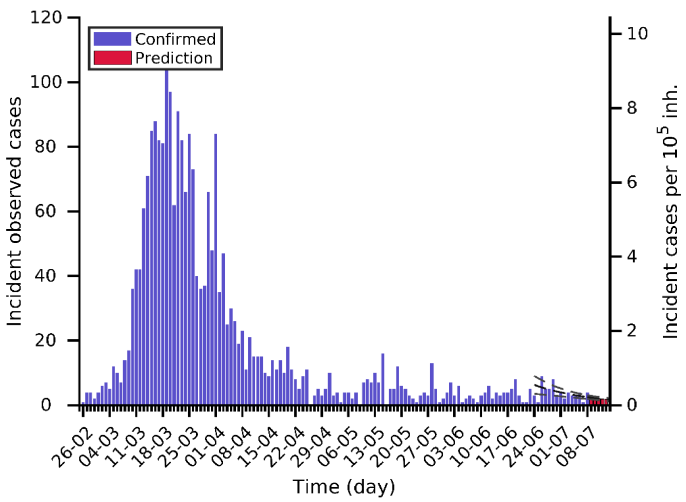


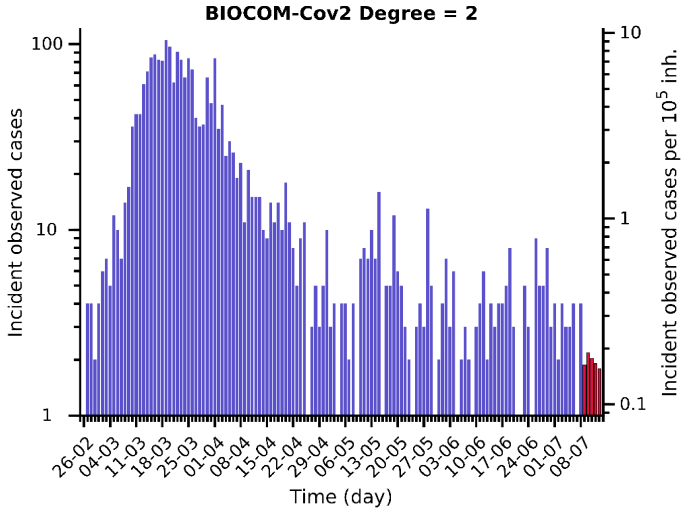


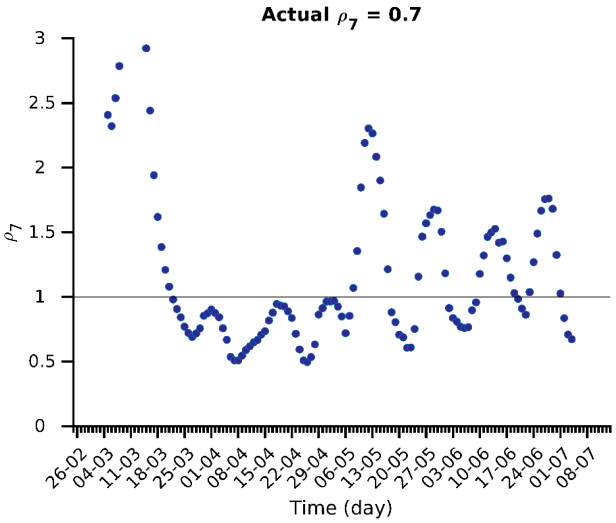
Baleares 08-07-2020. Pop: 1.1M. Cumulative incidence: 207/10⁵



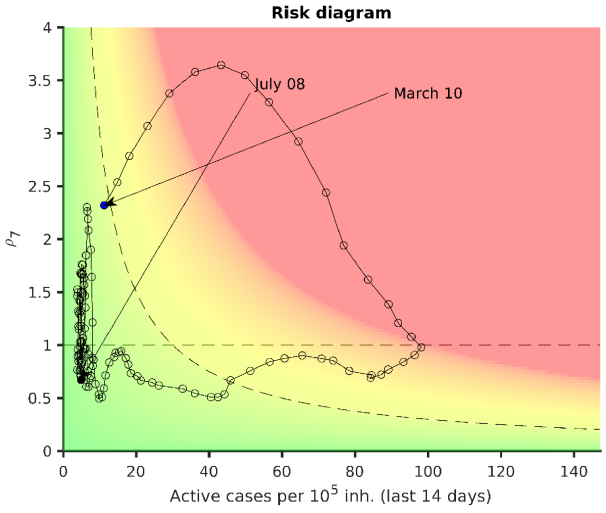
Deaths series currently under revision

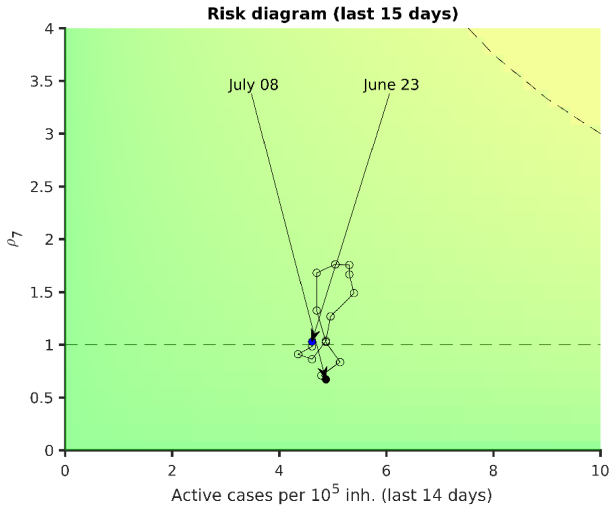




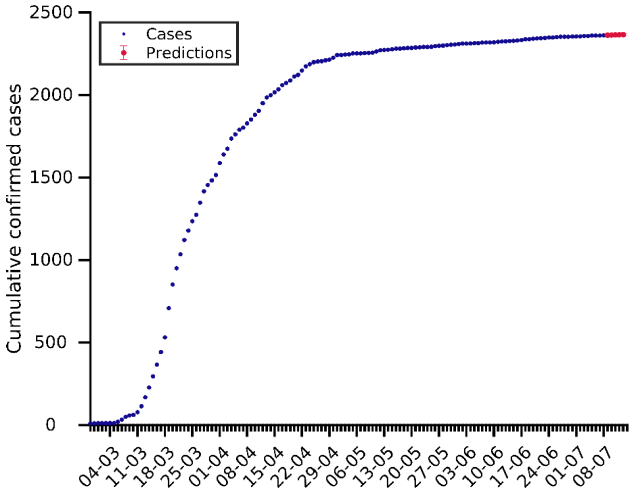


Deaths series currently under revision

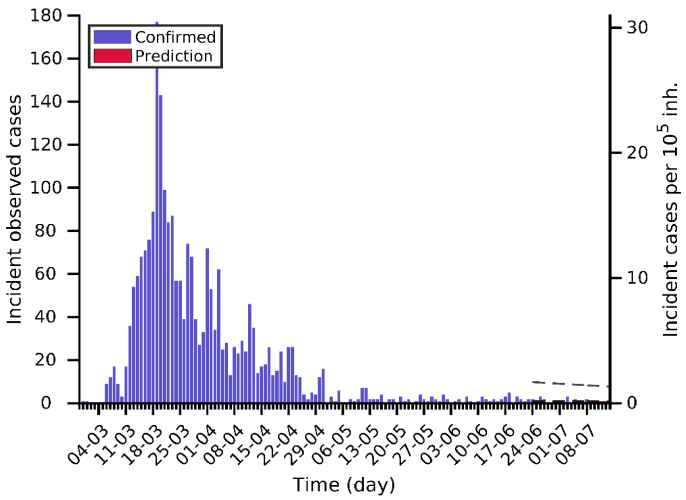


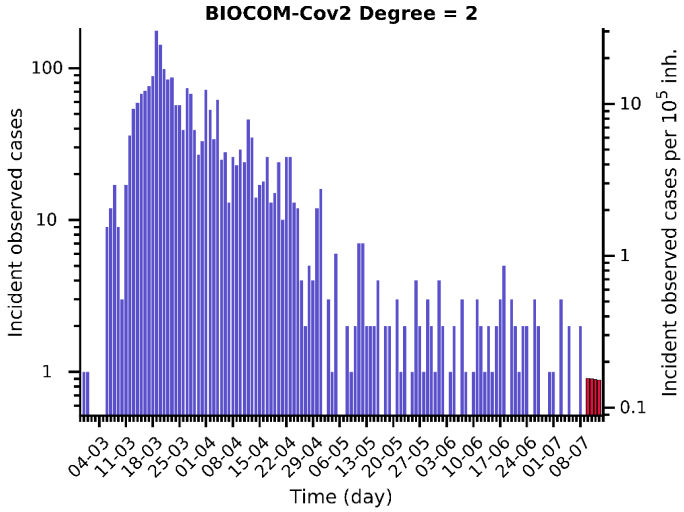


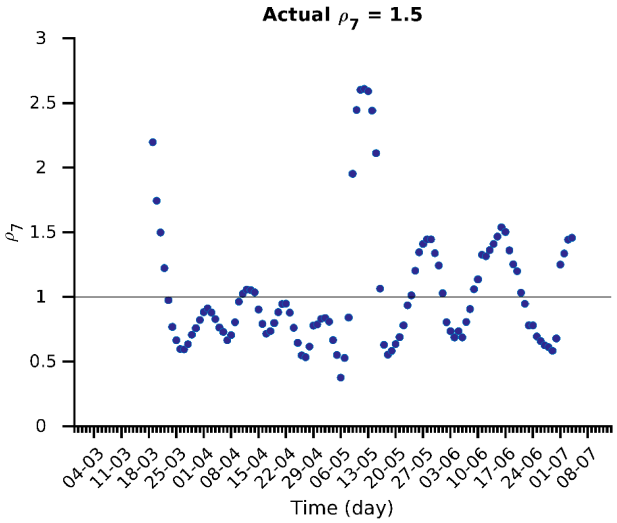
Cantabria 08-07-2020. Pop: 0.6M. Cumulative incidence: 406/10⁵



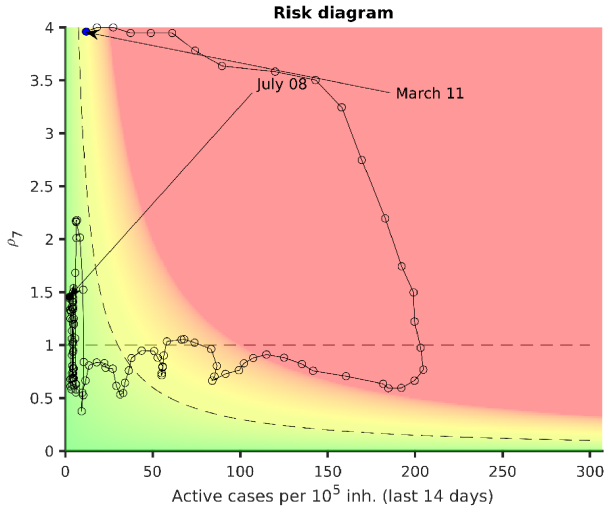
Deaths series currently under revision

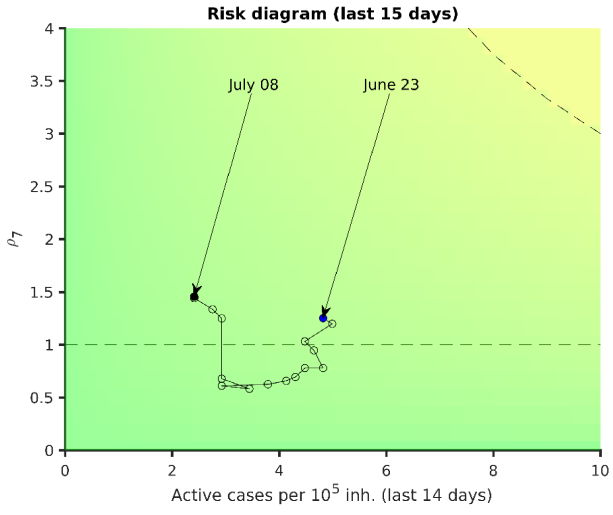




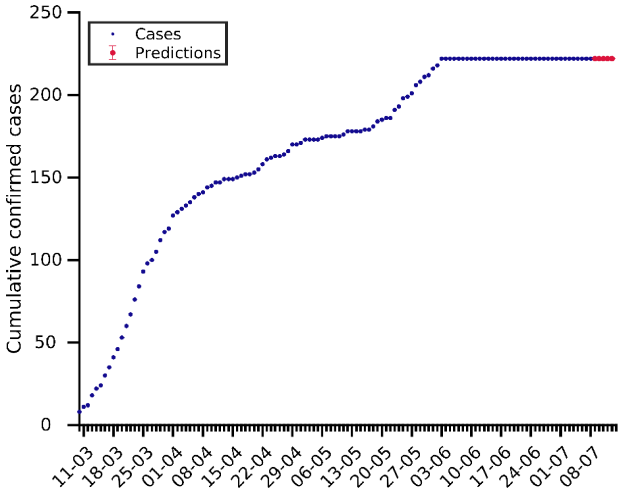


Deaths series currently under revision

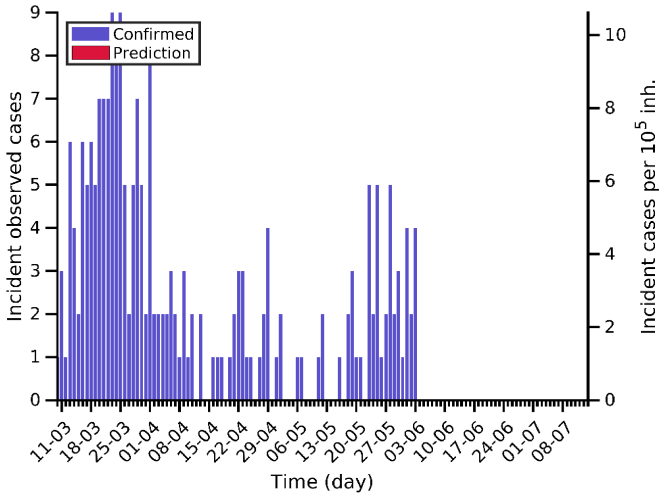


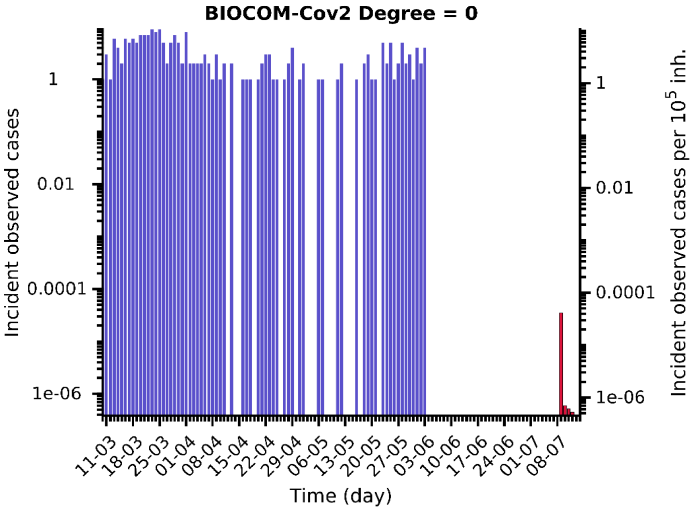


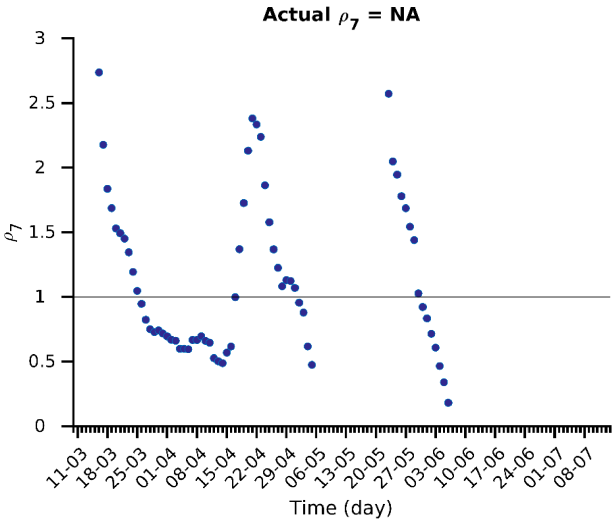
Ceuta 08-07-2020. Pop: 0.1M. Cumulative incidence: 262/10⁵



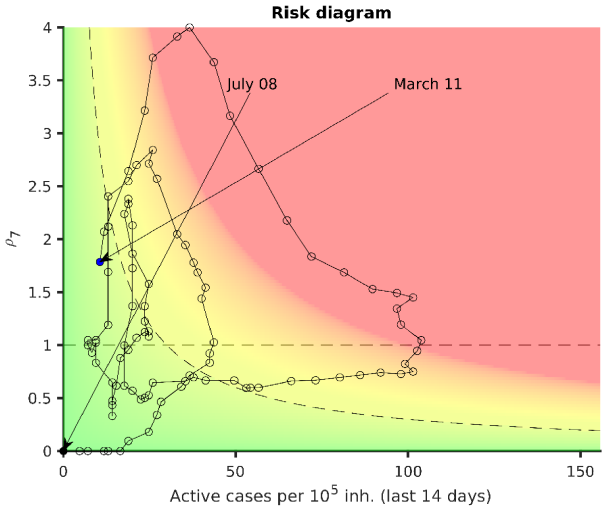
Deaths series currently under revision

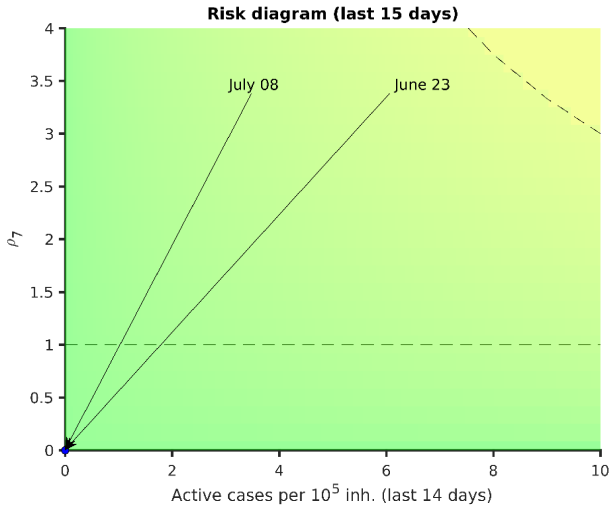






Deaths series currently under revision

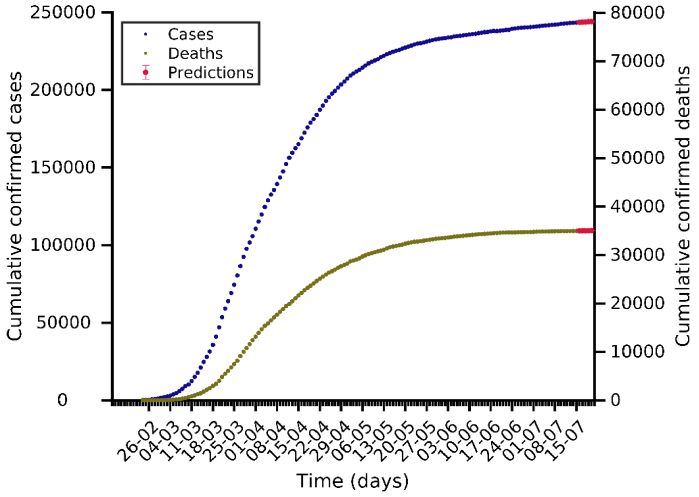


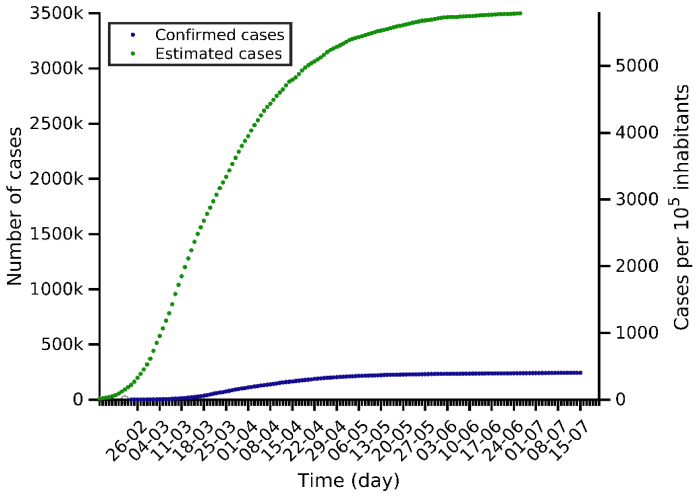


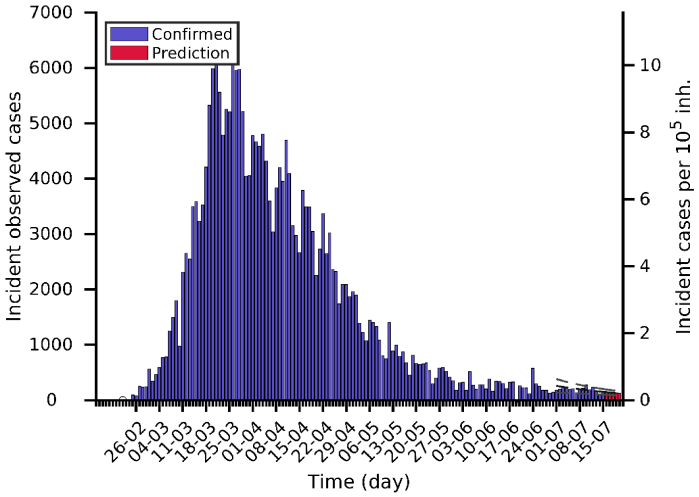
(3) Analysis and prediction of COVID-19 for Italy and its regions

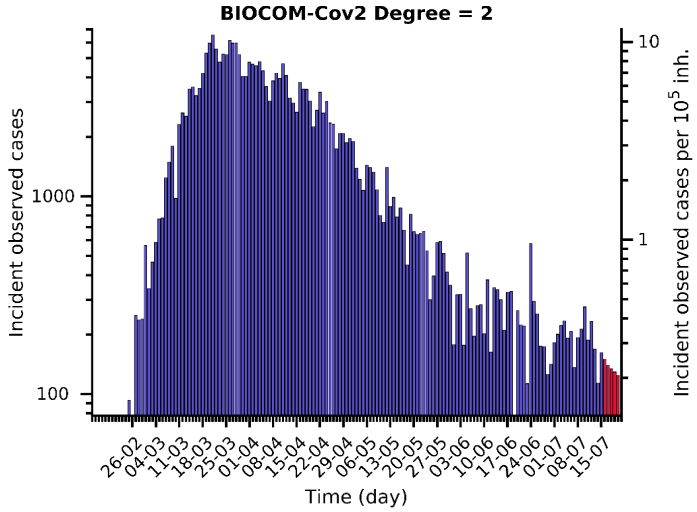
Data obtained from: https://github.com/pcm-dpc/COVID-19/tree/master/dati-andamento-nazionale

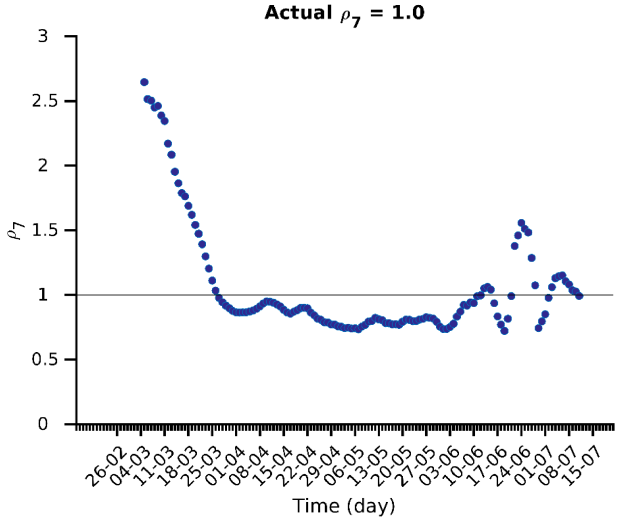
Italy 15-07-2020. Pop: 60.5M. Cumulative incidence: 403/10⁵

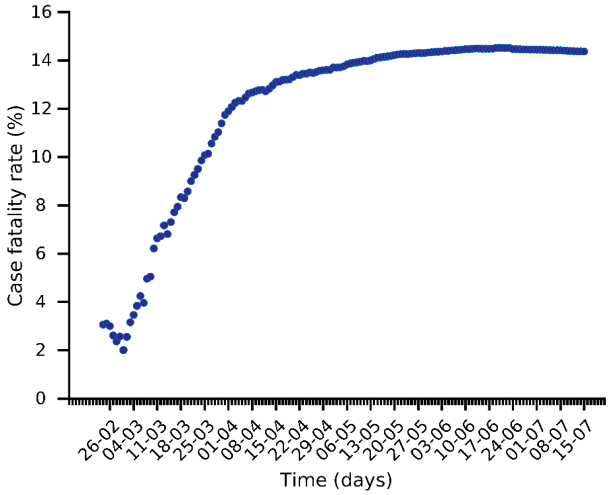


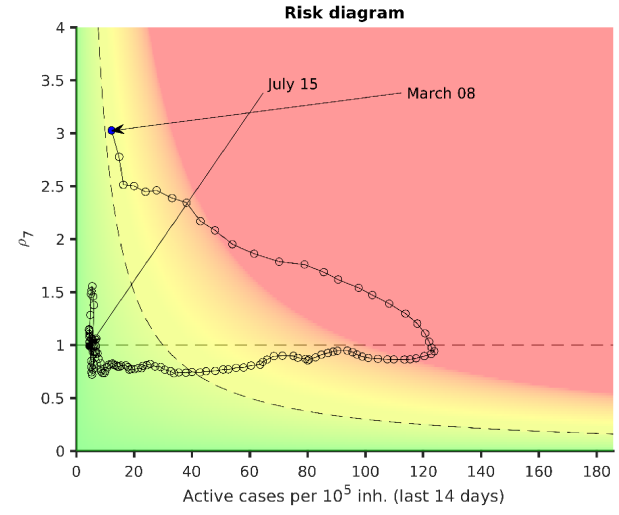


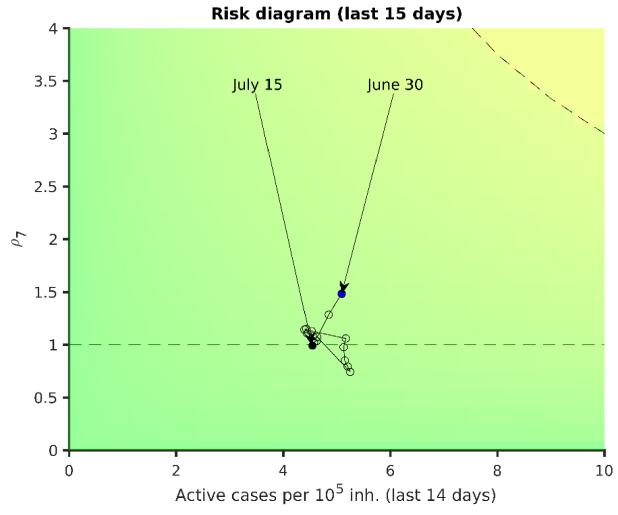




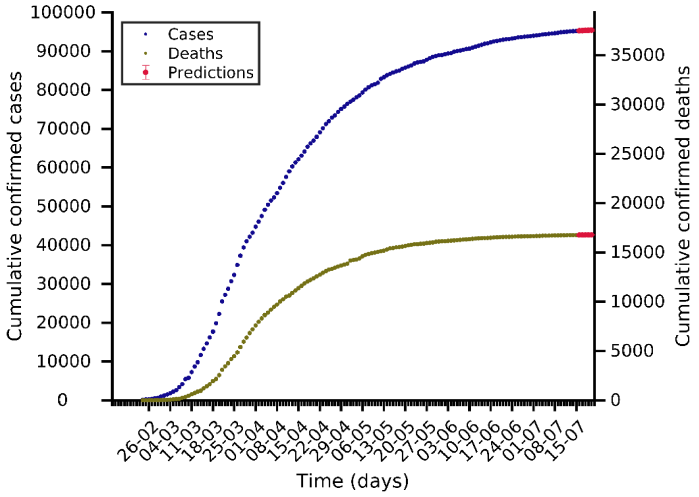


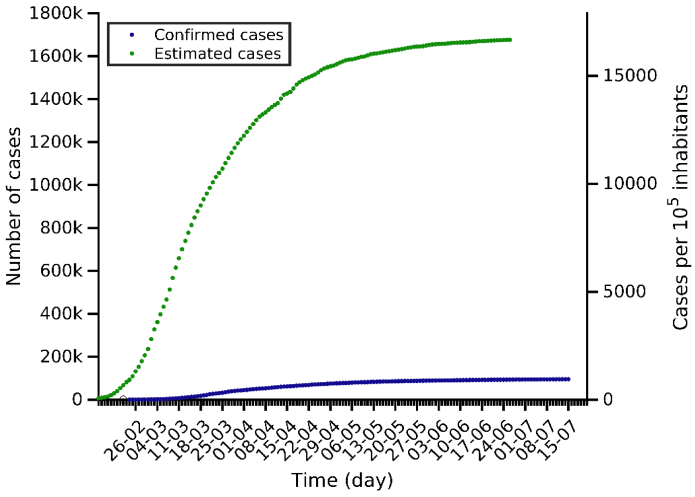


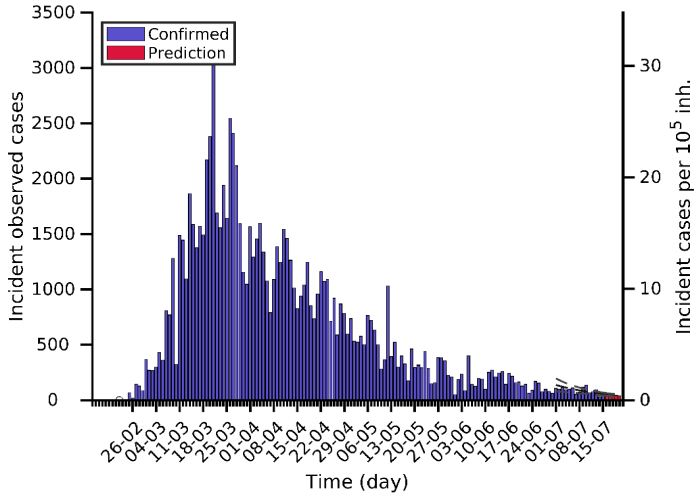


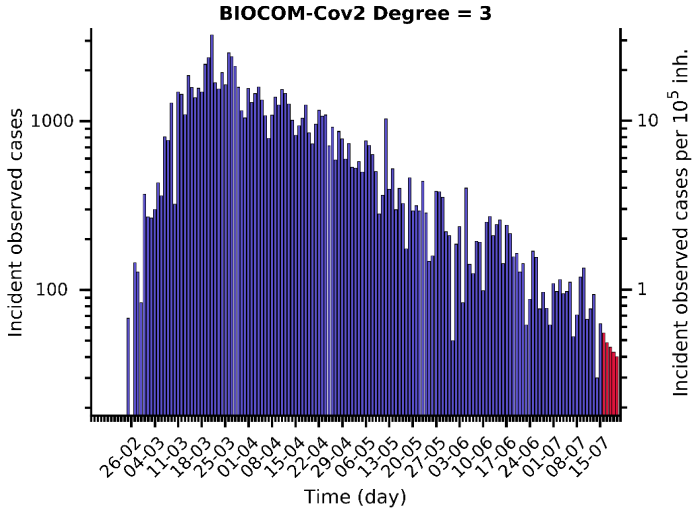


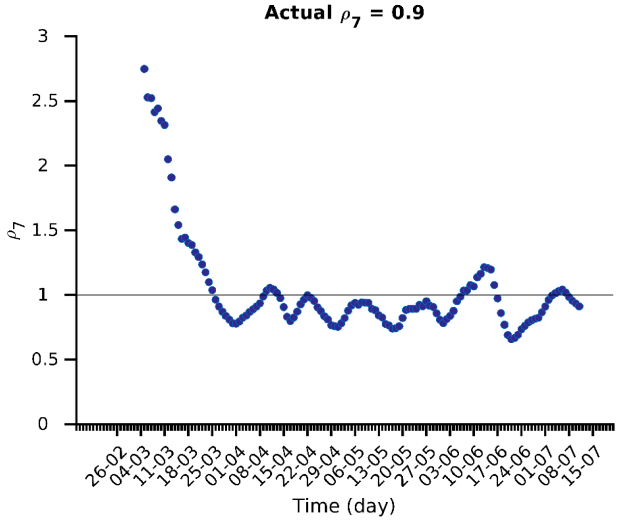
Lombardia 15-07-2020. Pop: 10.1M. Cumulative incidence: 947/10⁵

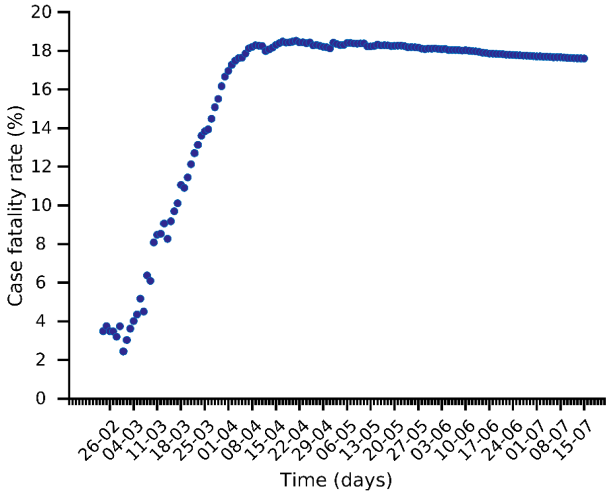


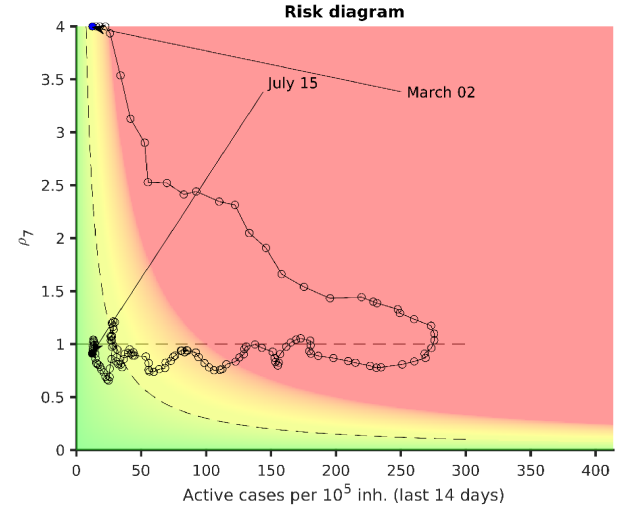


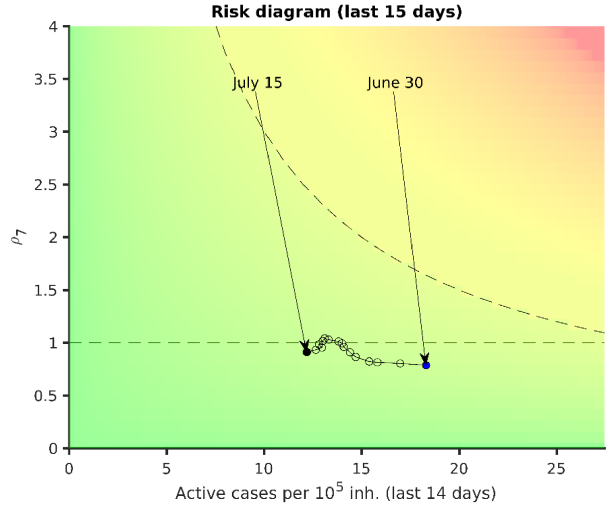




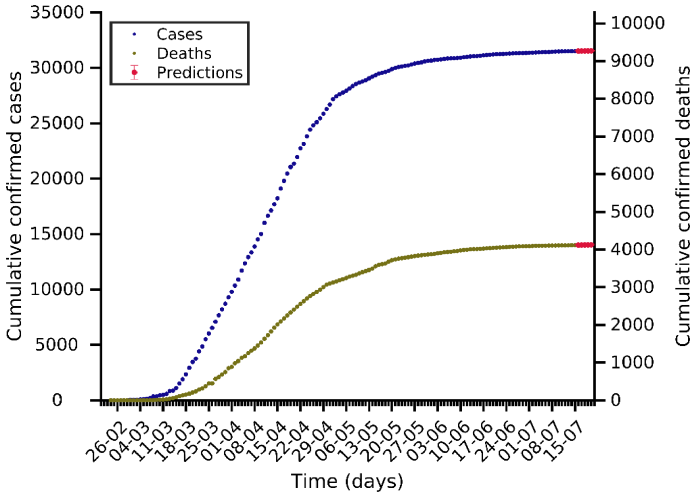


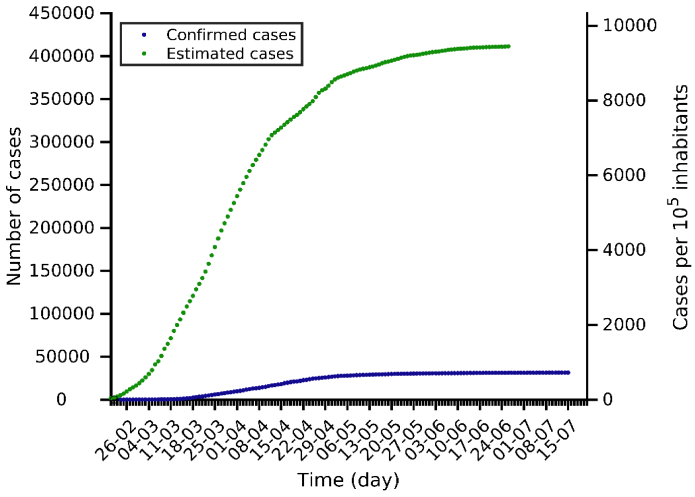


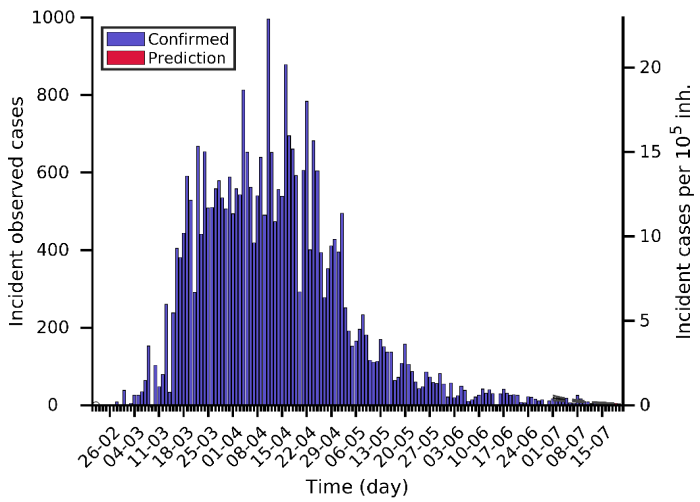


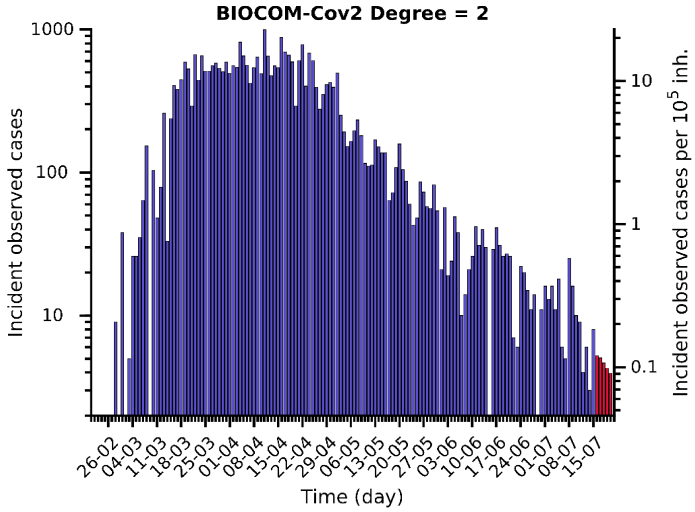


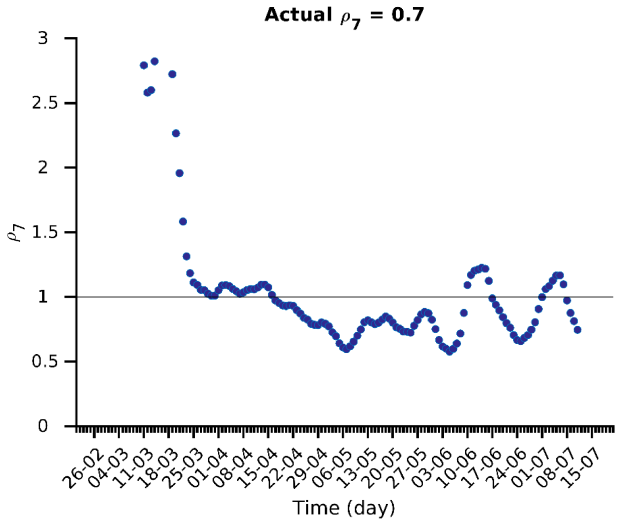
Piemonte 15-07-2020. Pop: 4.4M. Cumulative incidence: 723/10⁵

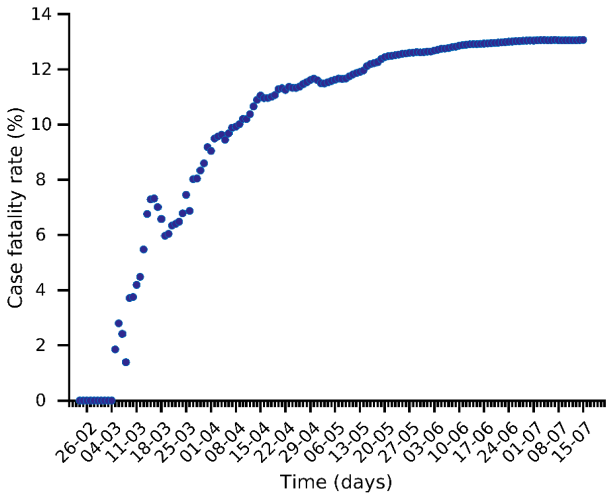


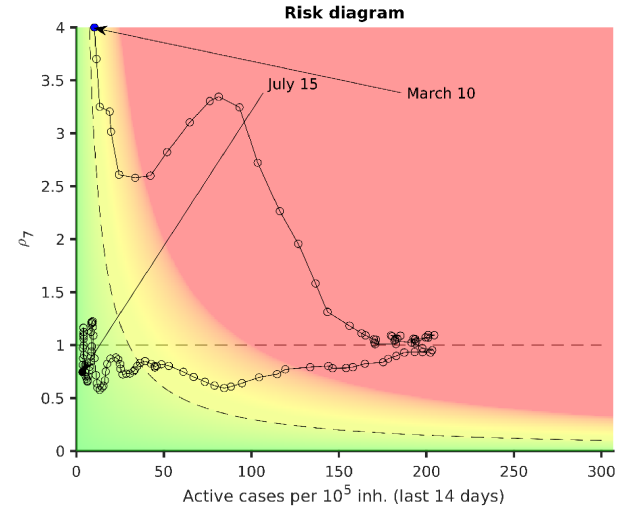


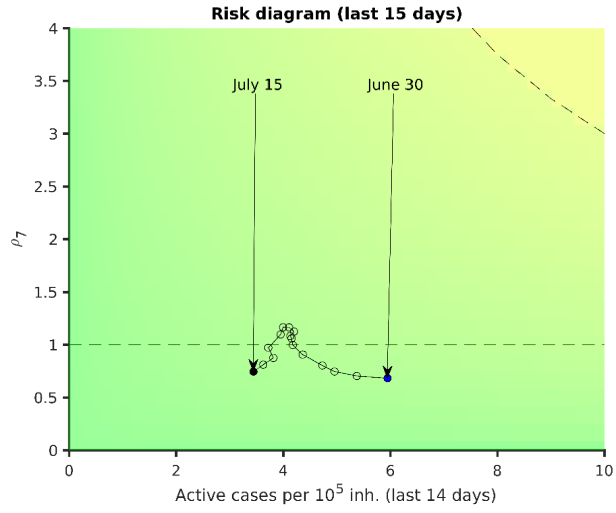




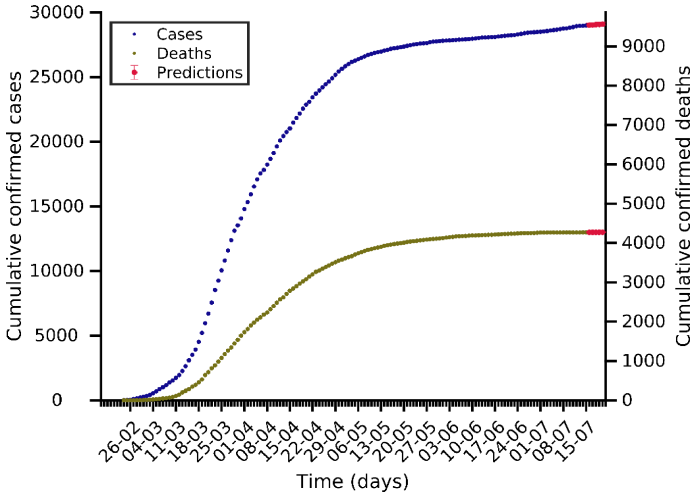


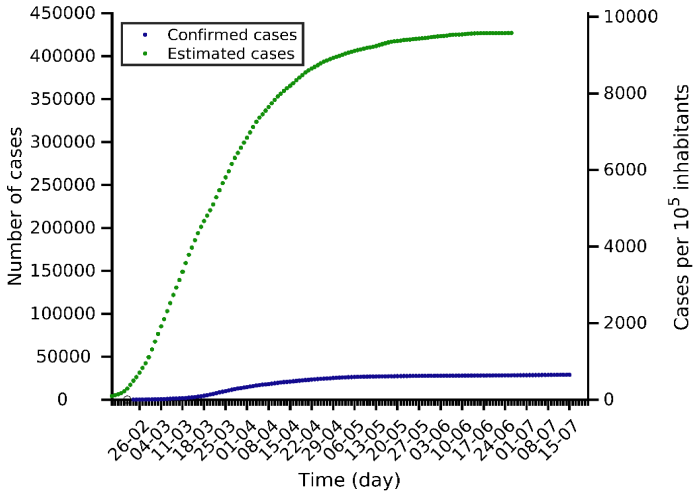


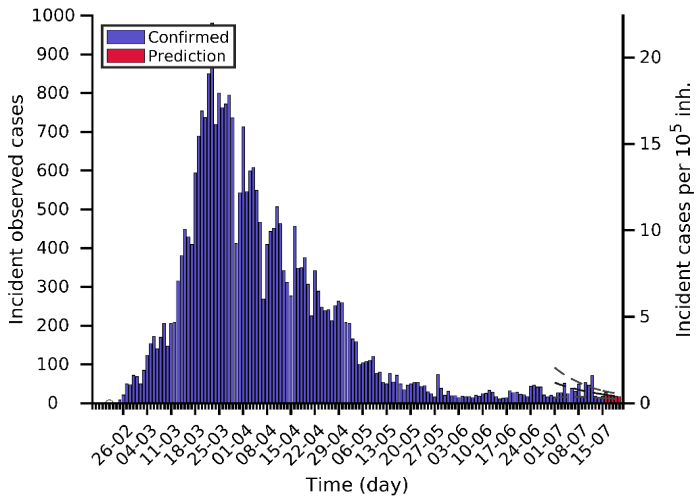


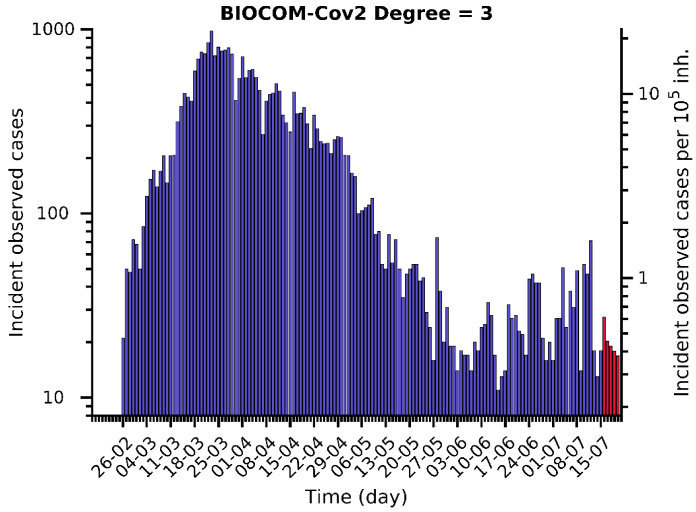


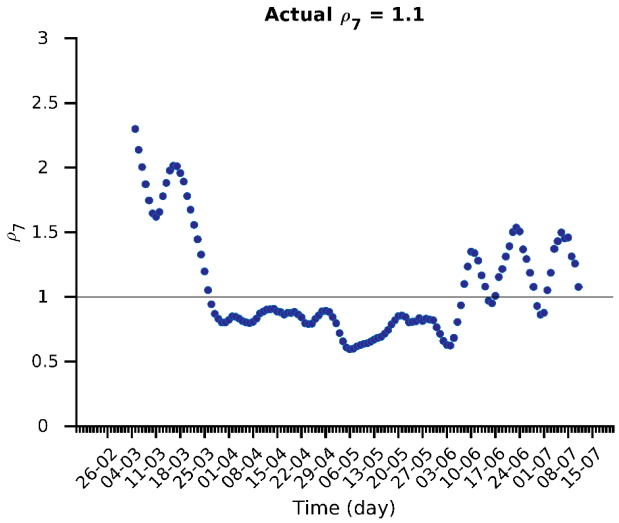
Emilia Romagna 15-07-2020. Pop: 4.5M. Cumulative incidence: 650/10⁵

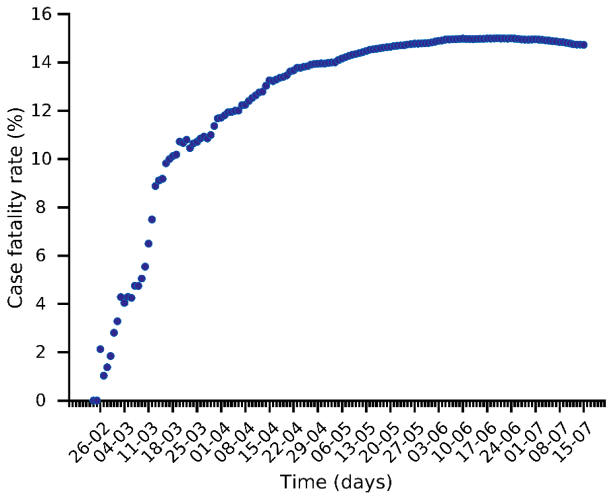


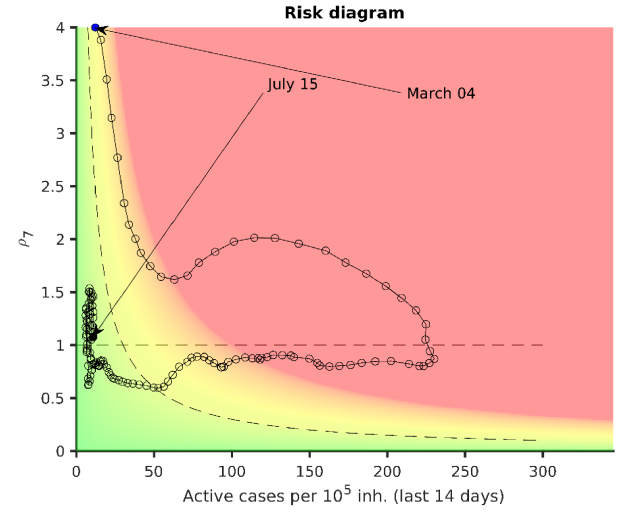


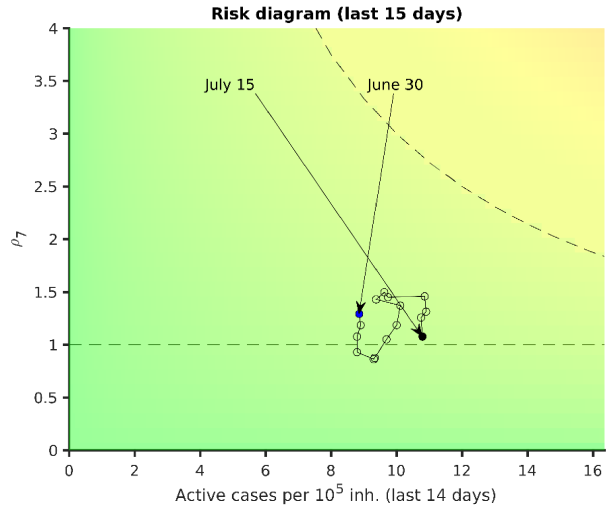




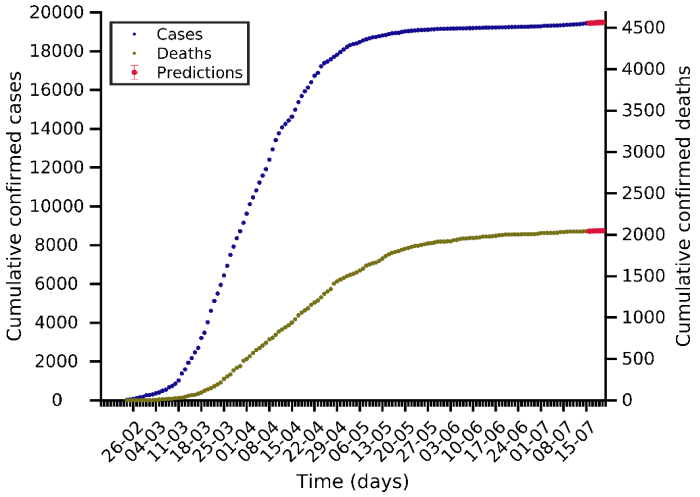


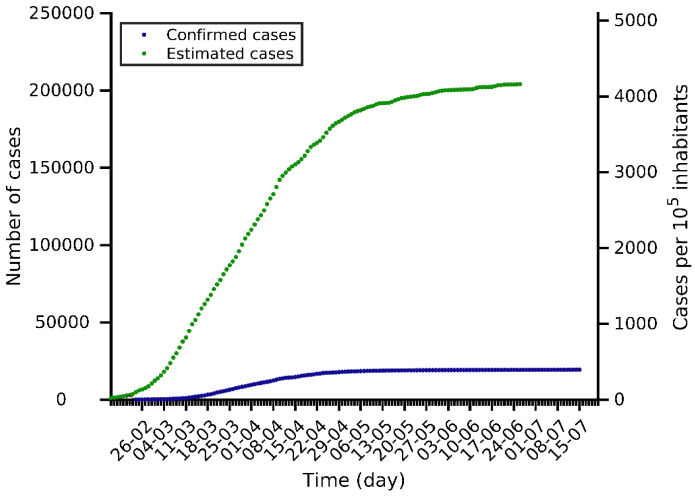


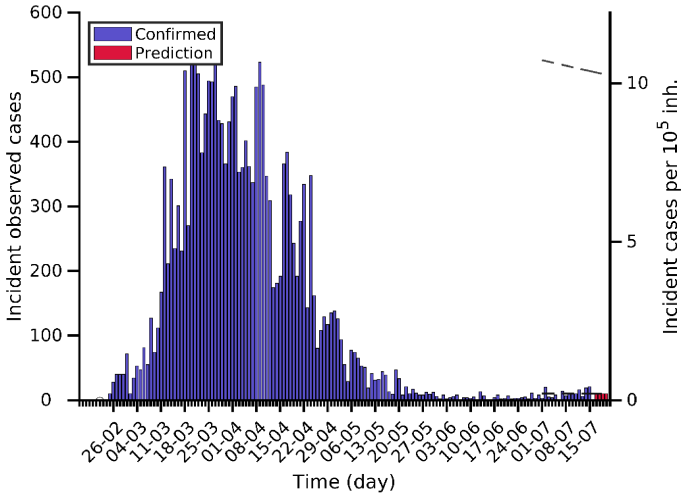


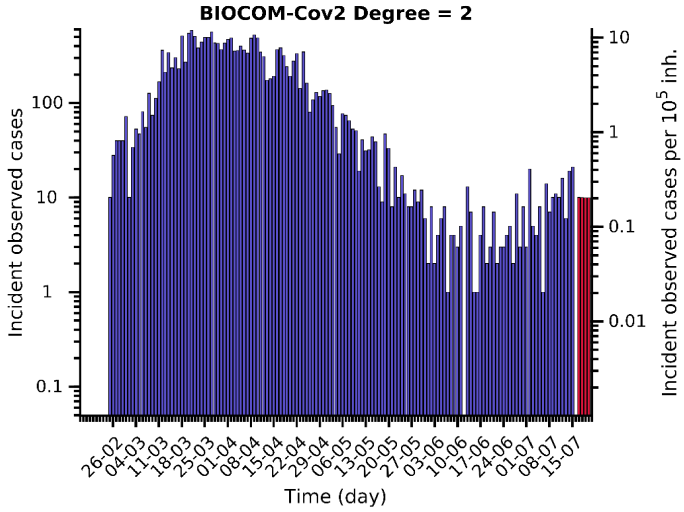


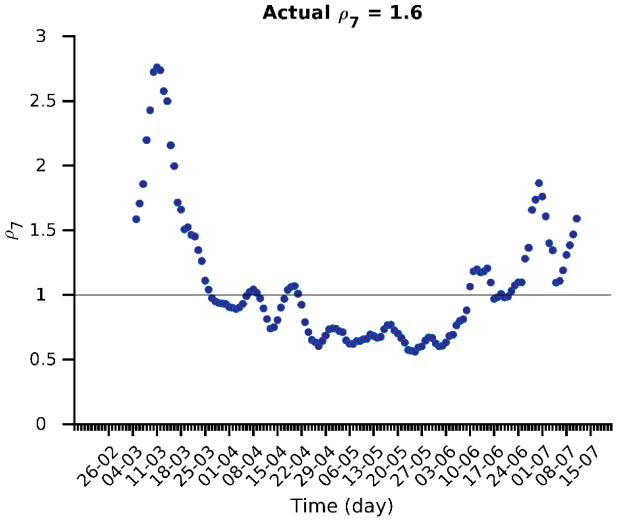
Veneto 15-07-2020. Pop: 4.9M. Cumulative incidence: 396/10⁵

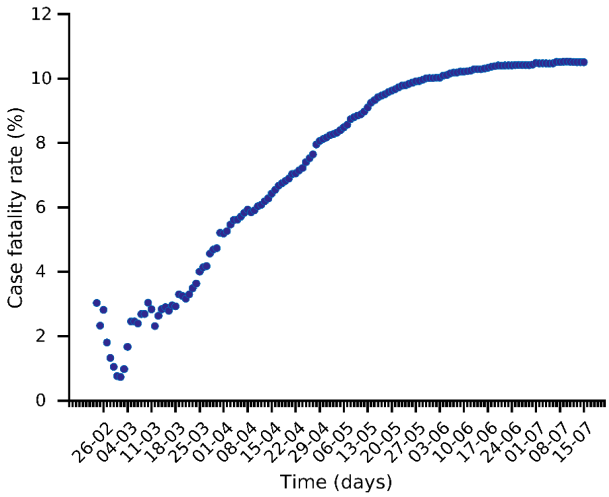


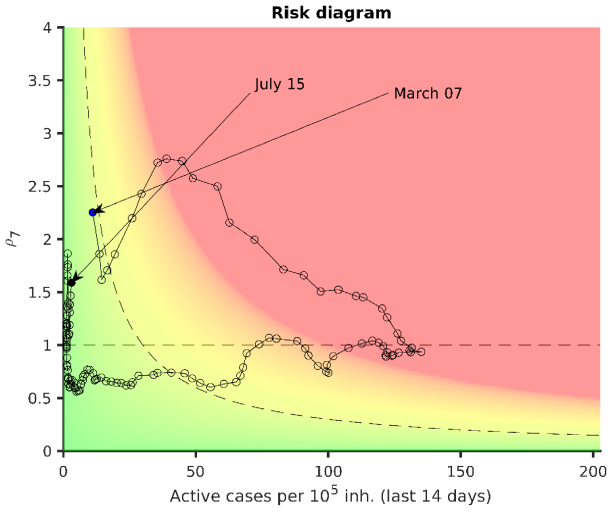


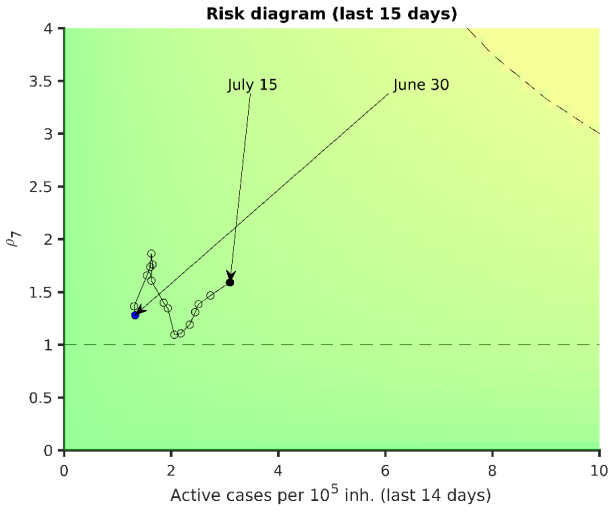




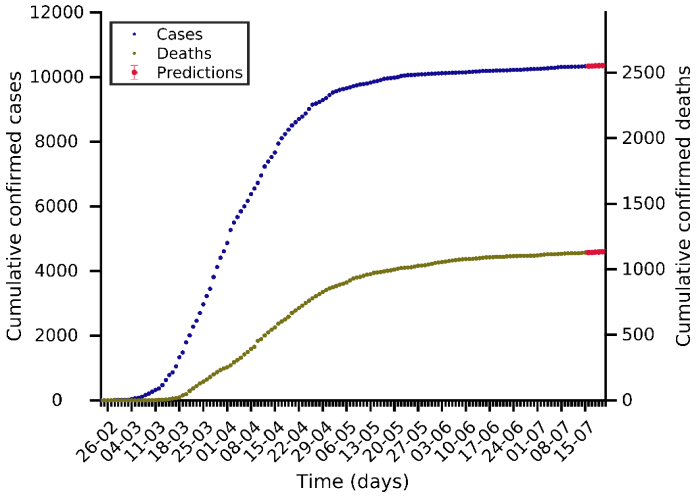


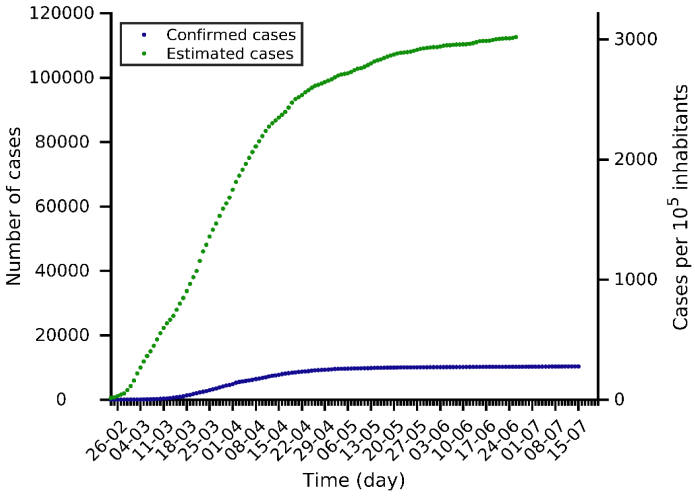


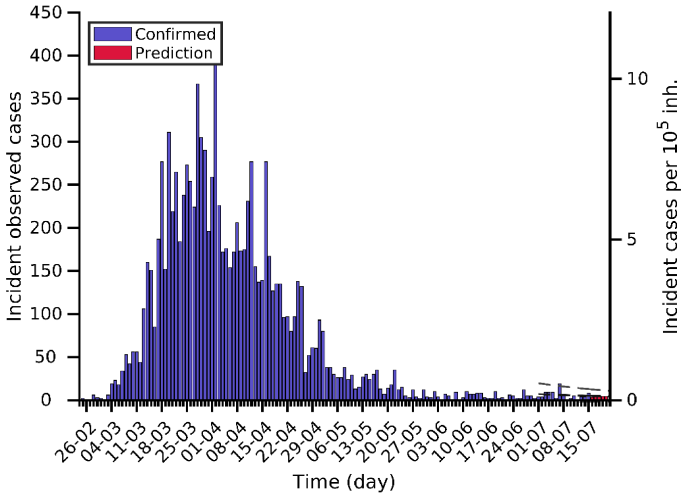


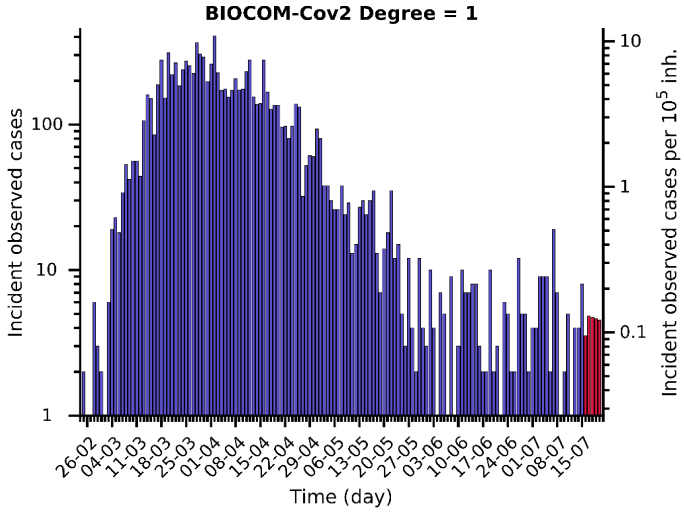


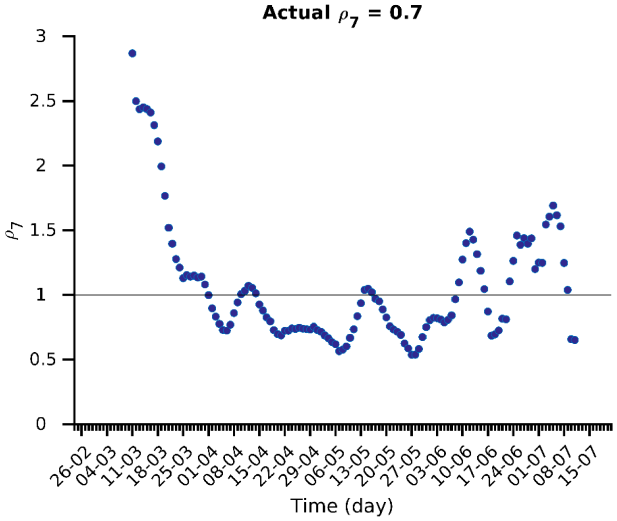
Toscana 15-07-2020. Pop: 3.7M. Cumulative incidence: 277/10⁵

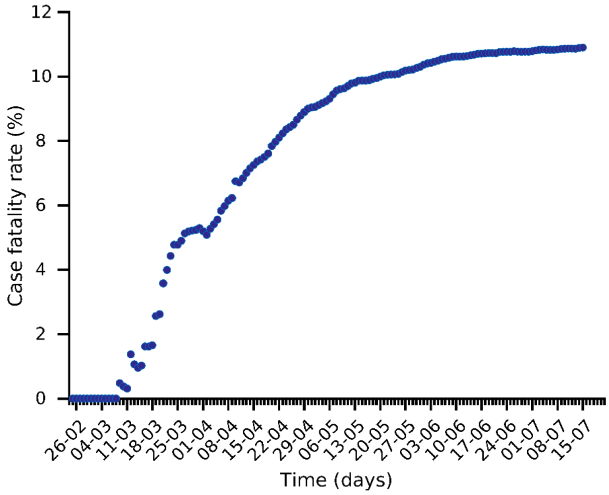


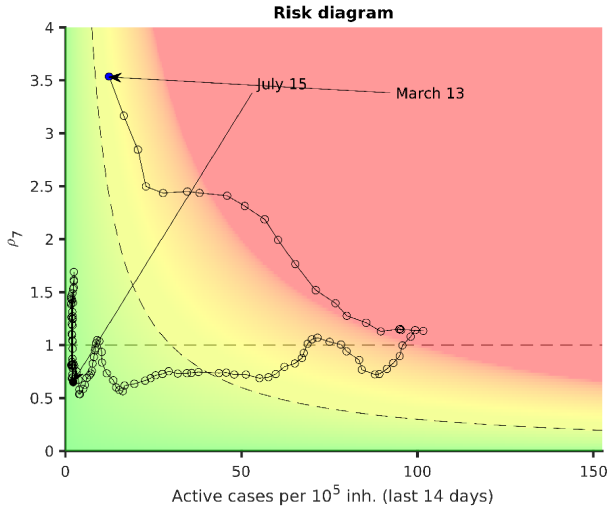


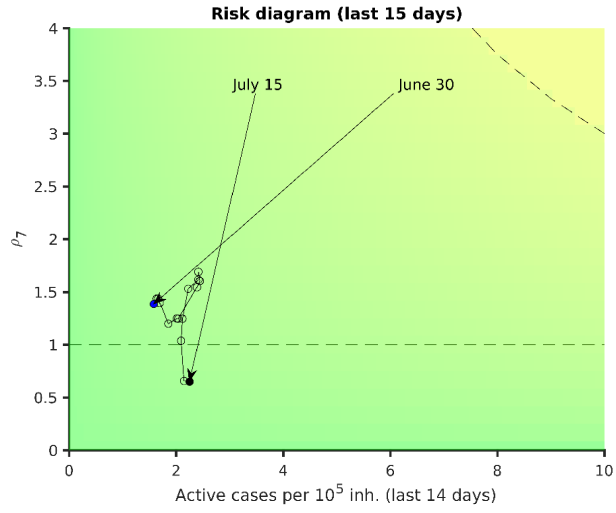




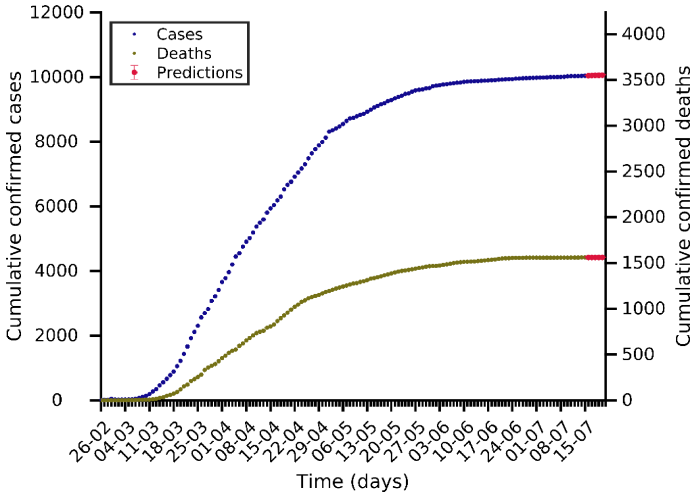


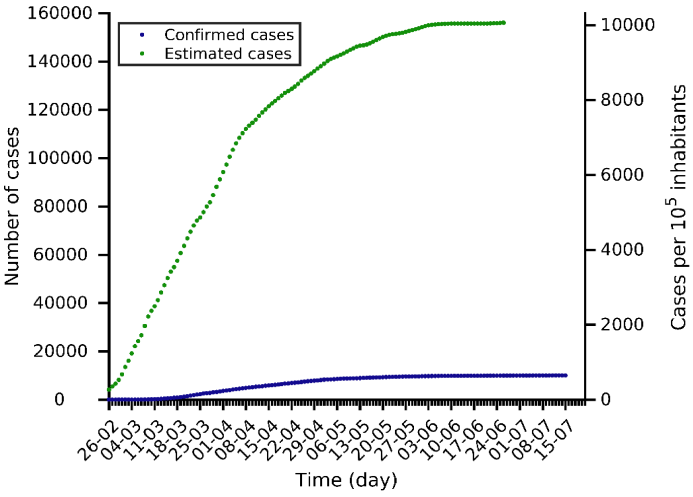


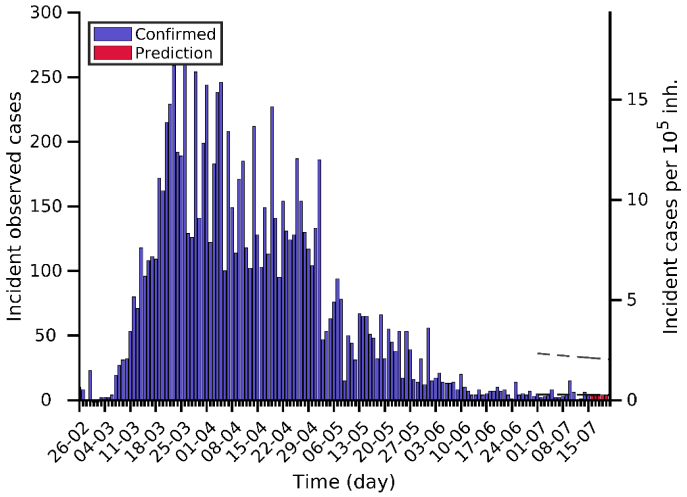


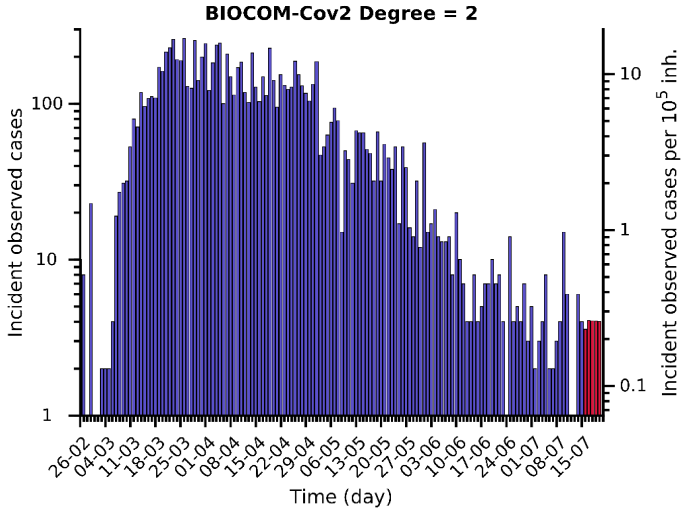


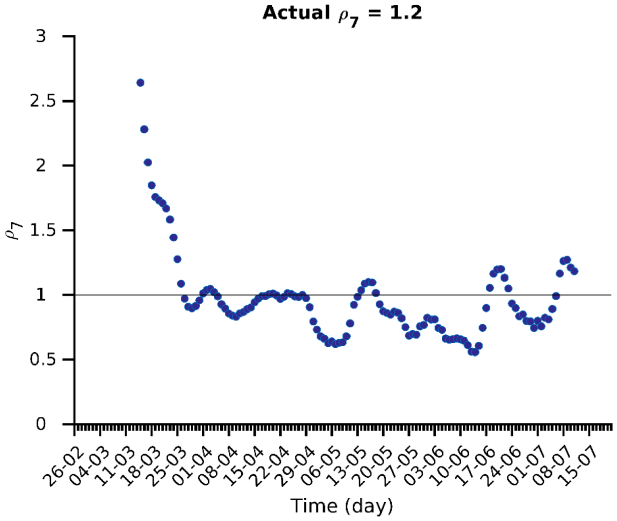
Liguria 15-07-2020. Pop: 1.6M. Cumulative incidence: 647/10⁵

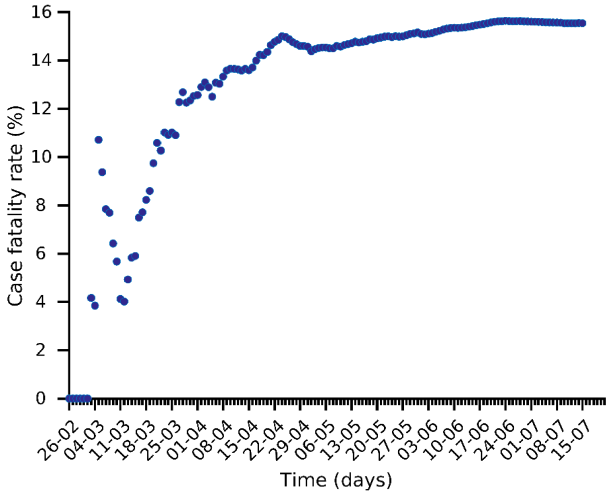


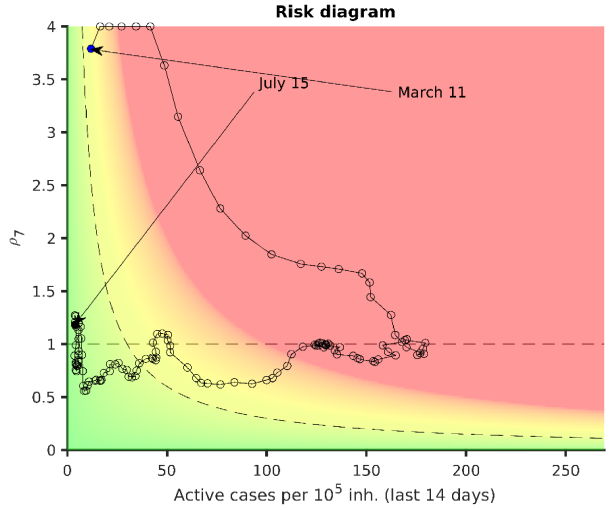


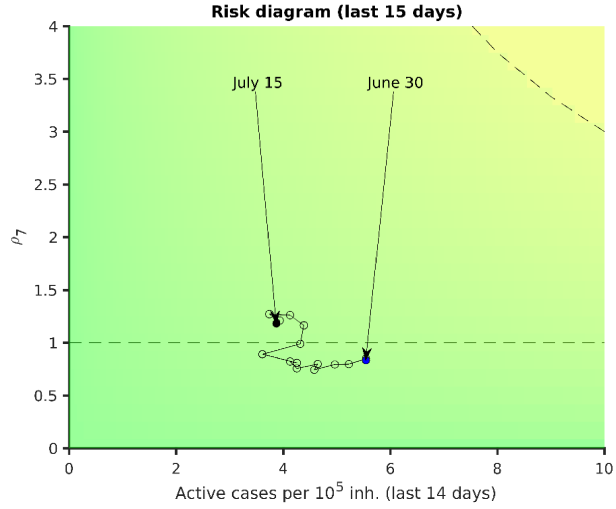




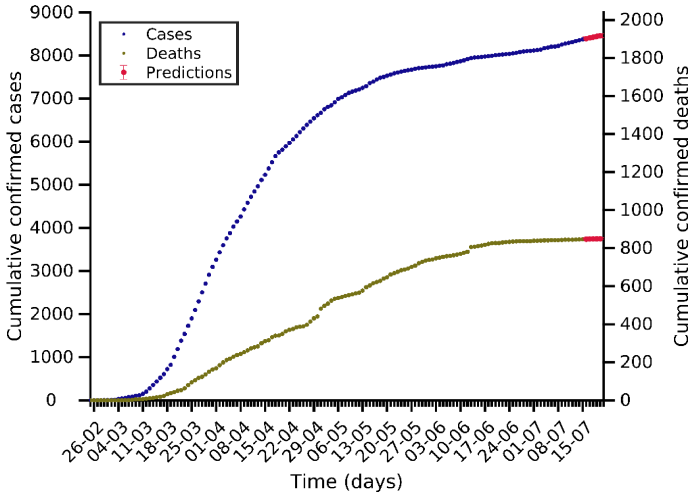


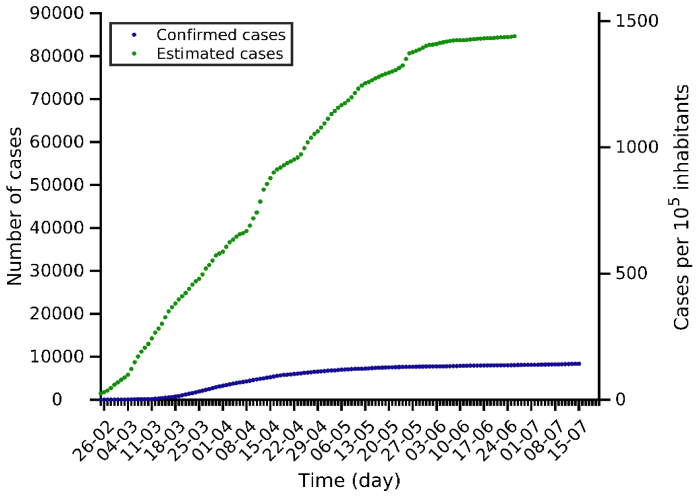


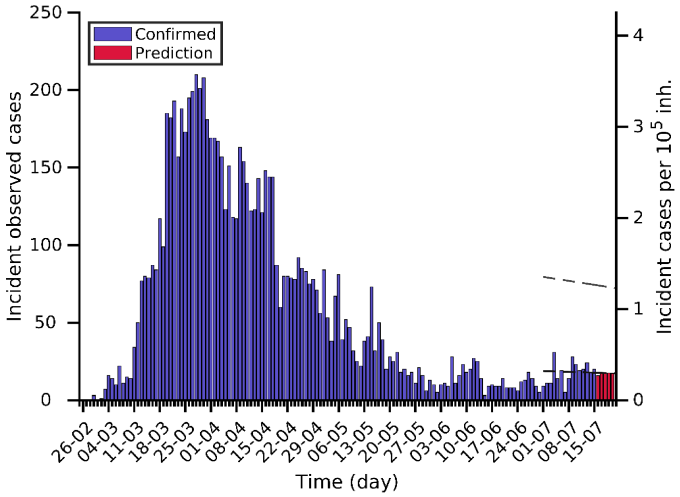


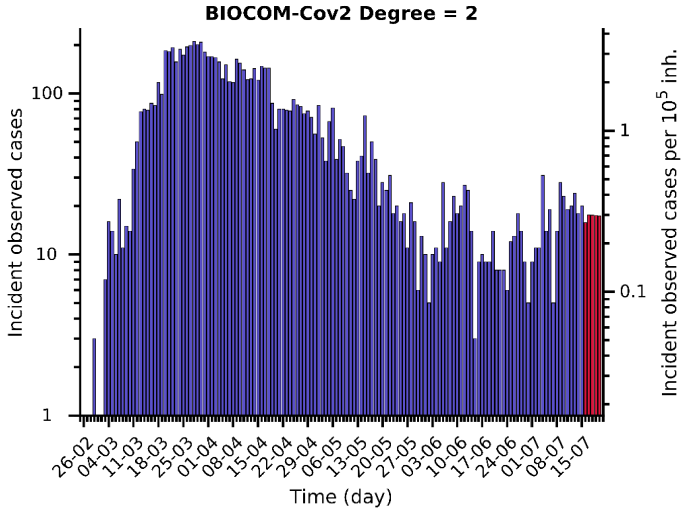


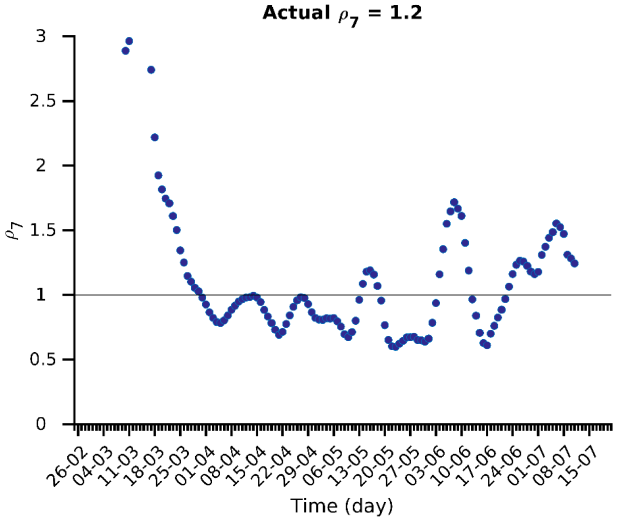
Lazio 15-07-2020. Pop: 5.9M. Cumulative incidence: 142/10⁵

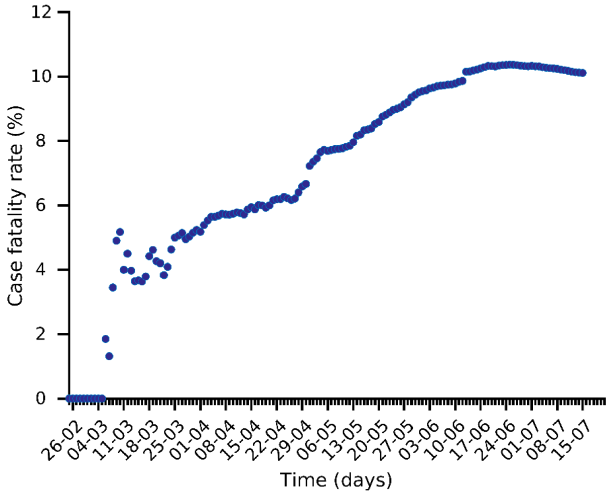


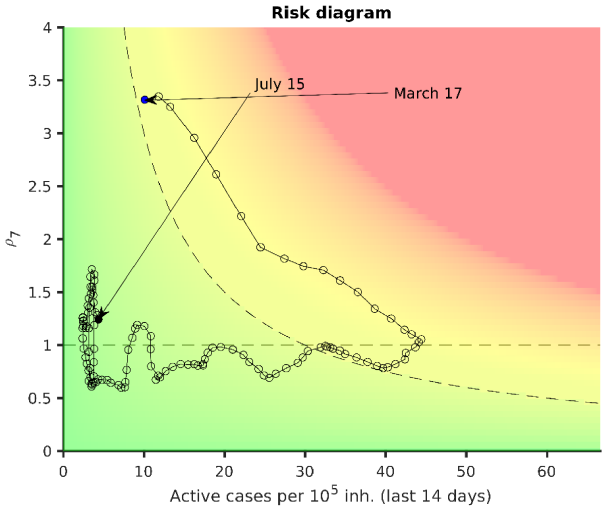


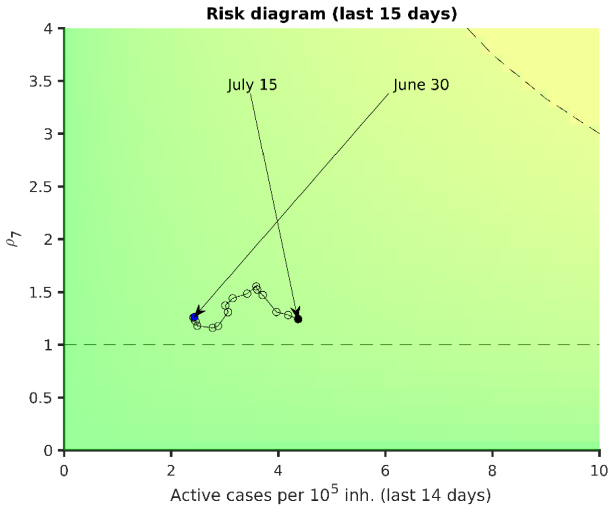




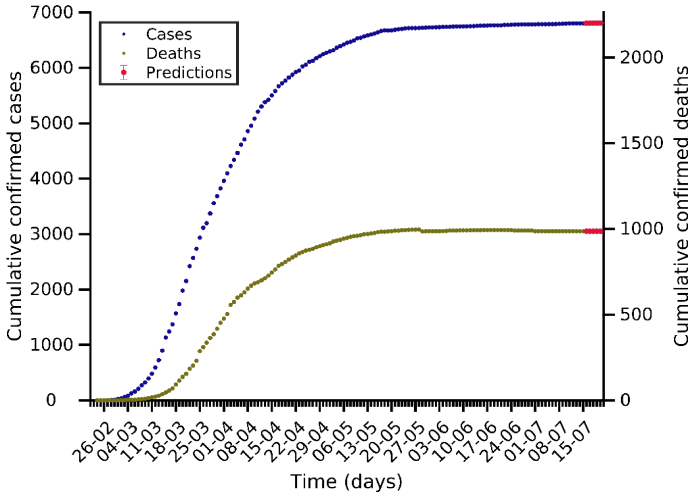


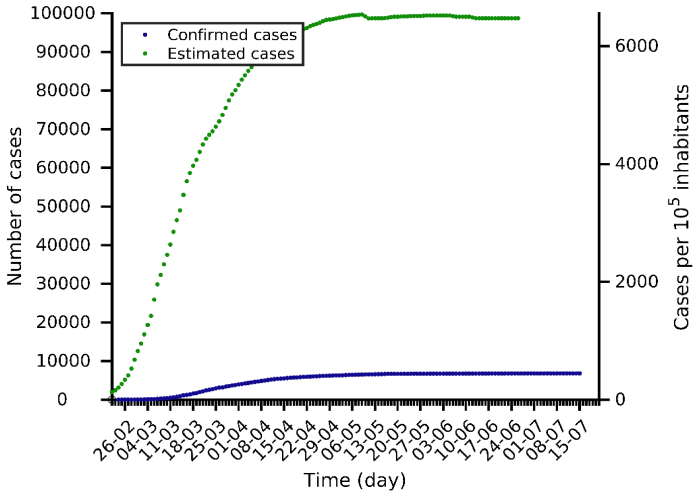


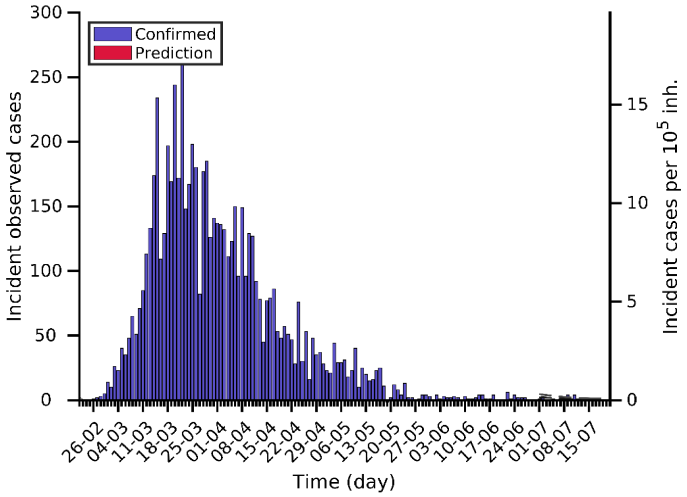


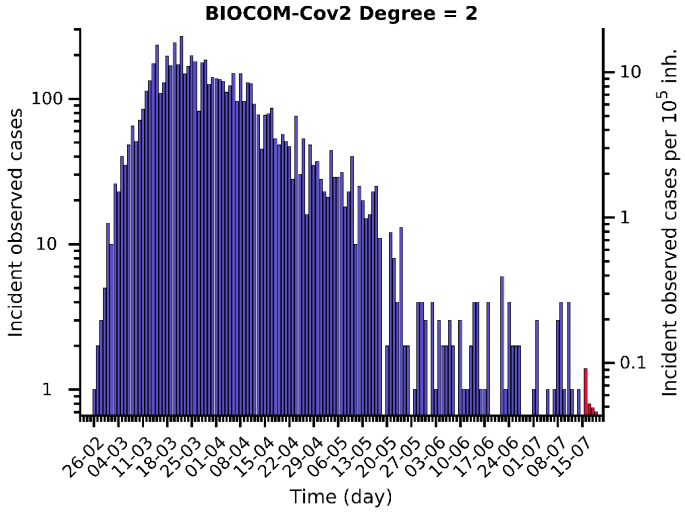


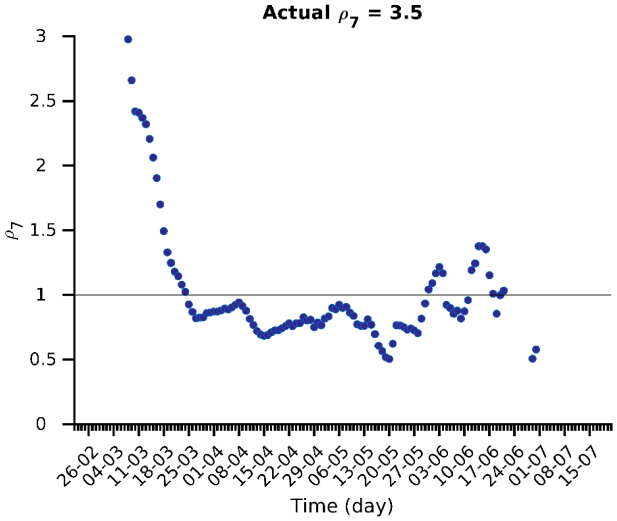
Marche 15-07-2020. Pop: 1.5M. Cumulative incidence: 446/10⁵

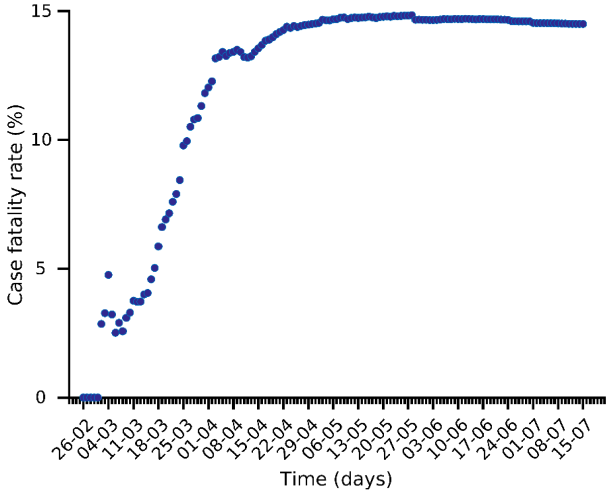


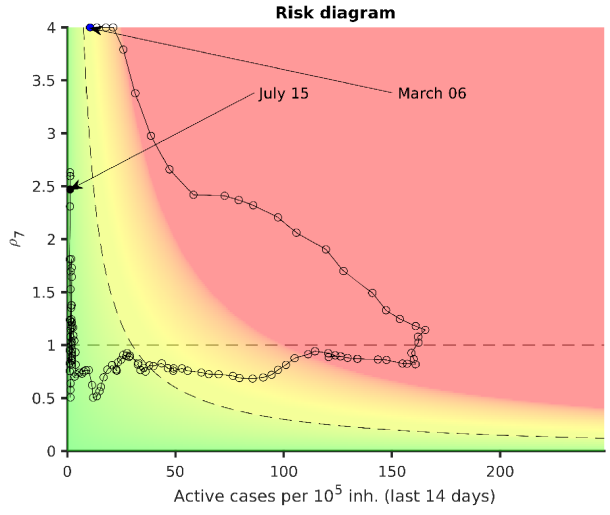


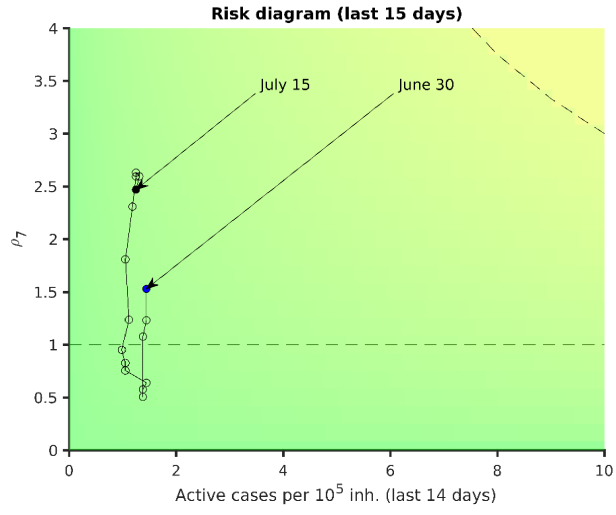




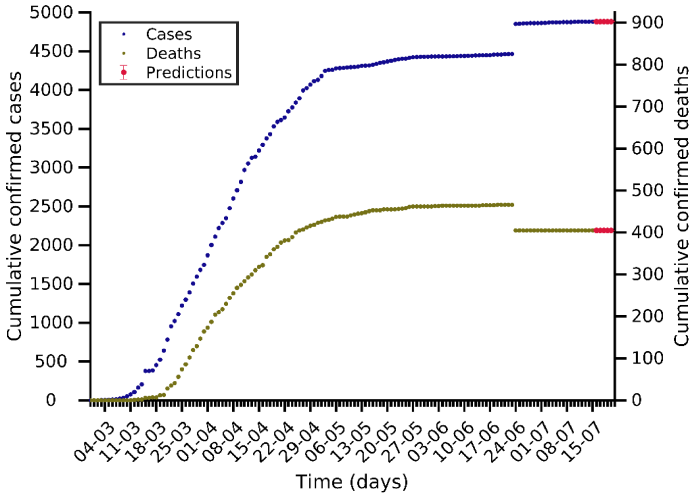


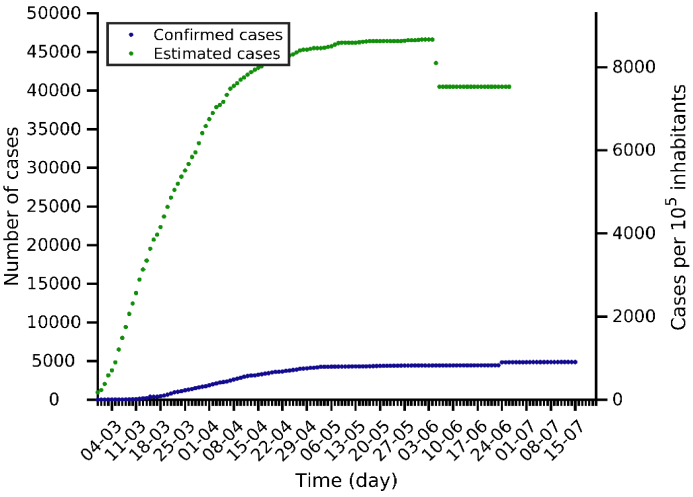


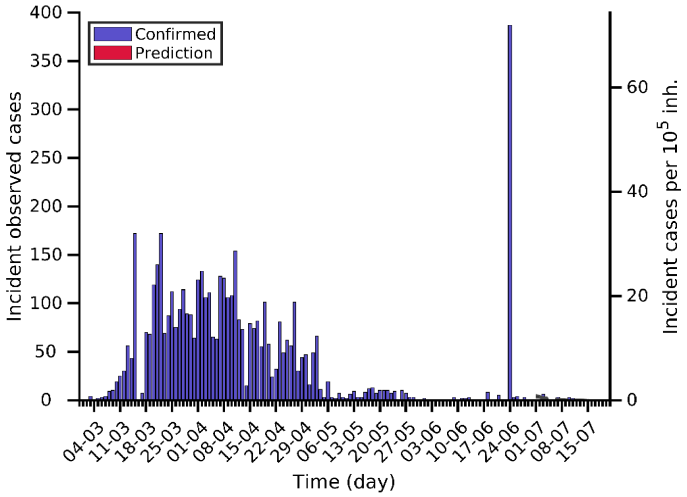


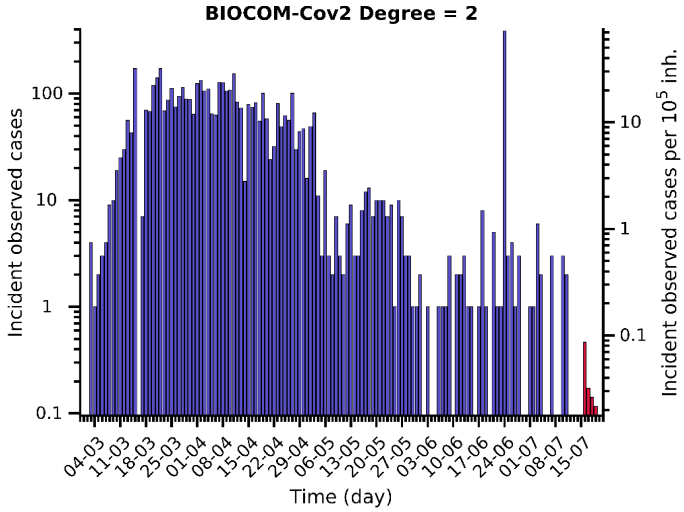


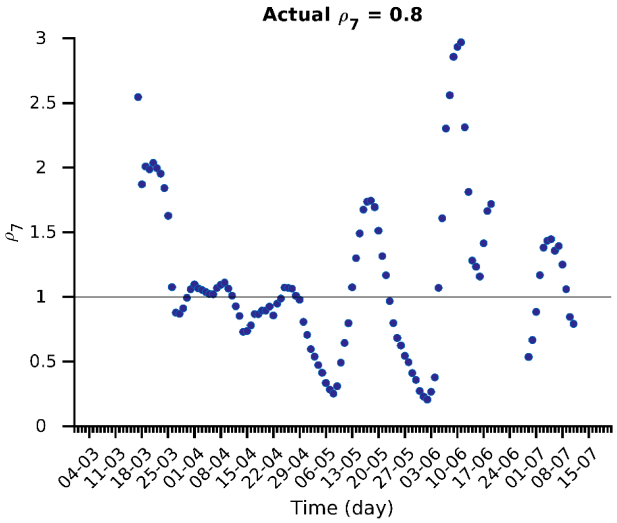
Trento 15-07-2020. Pop: 0.5M. Cumulative incidence: 907/10⁵

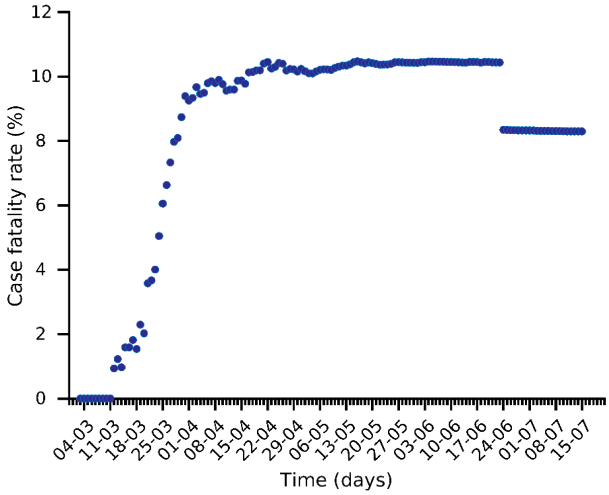


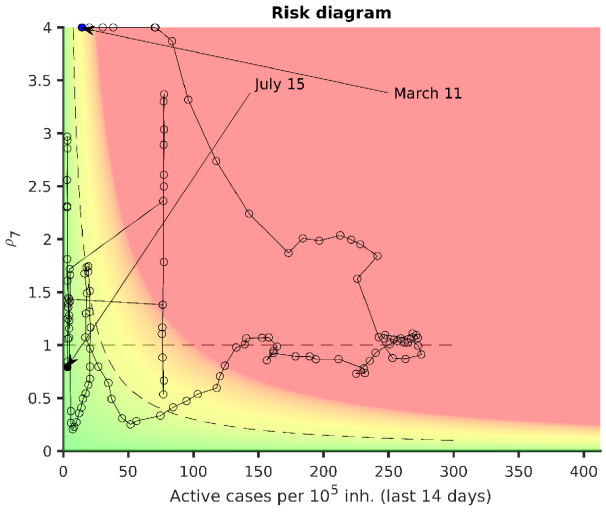


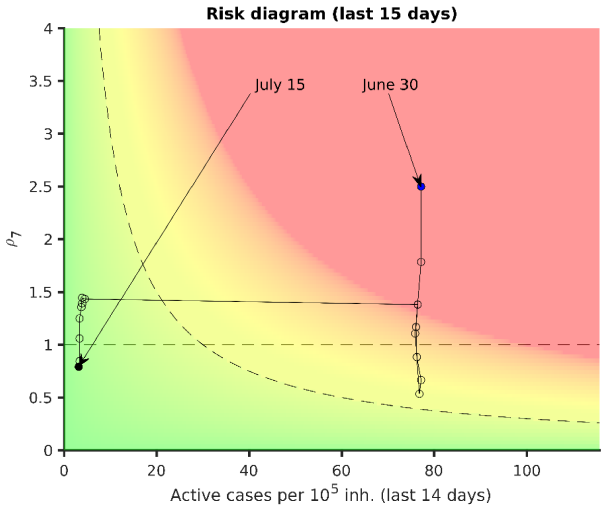




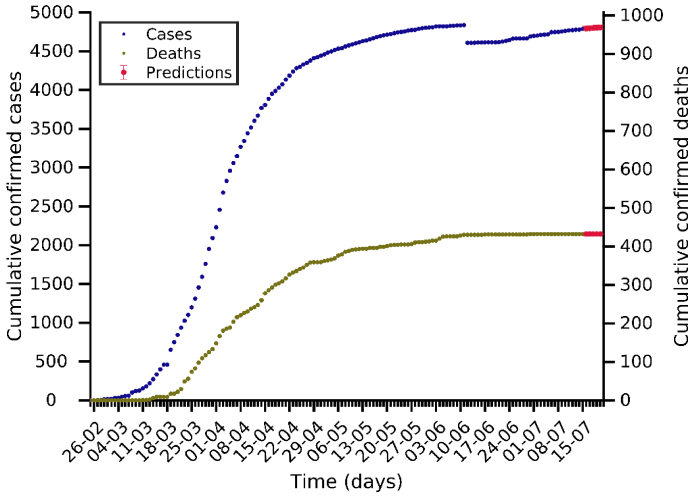


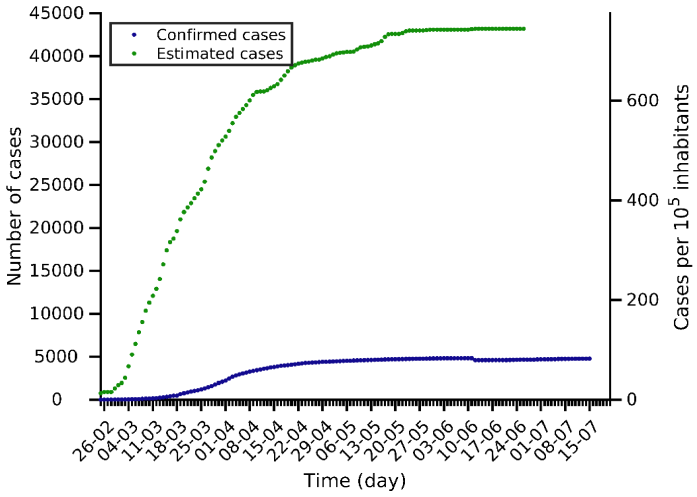


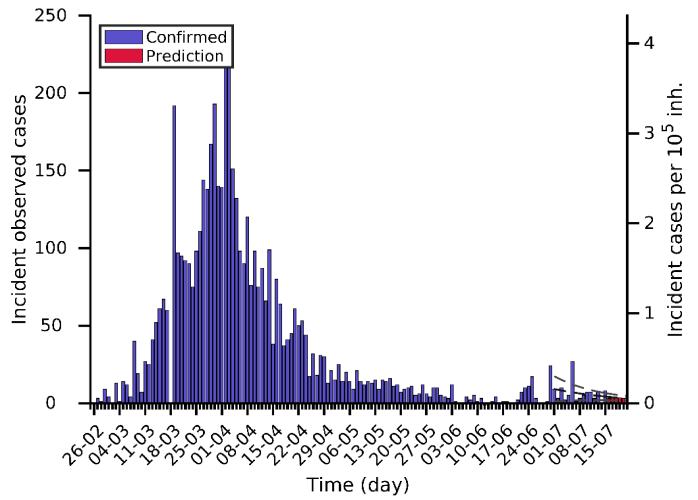


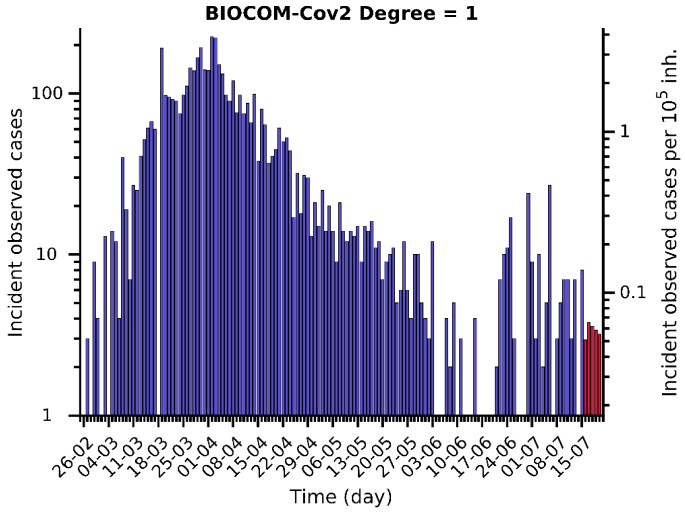


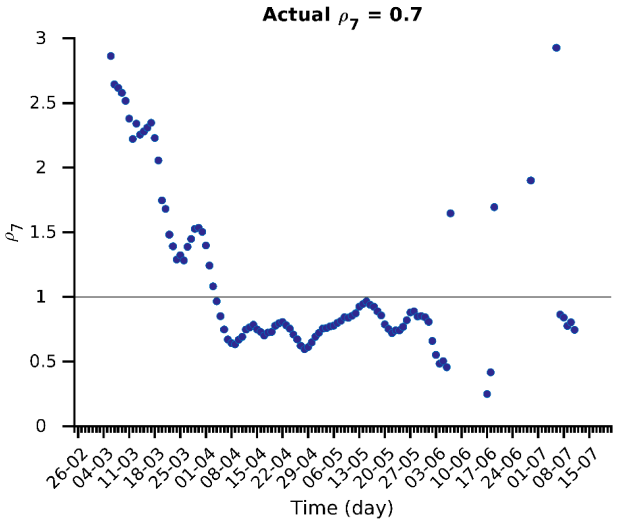
Campania 15-07-2020. Pop: 5.8M. Cumulative incidence: 83/10^5

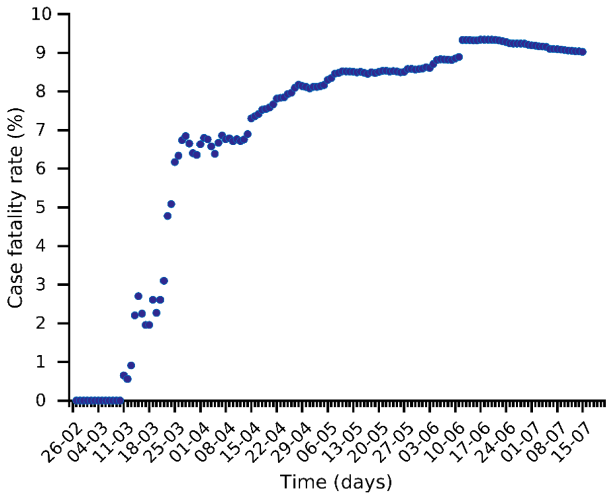


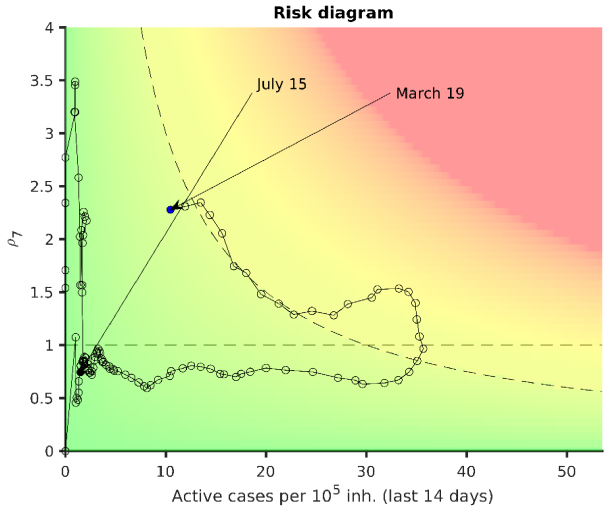


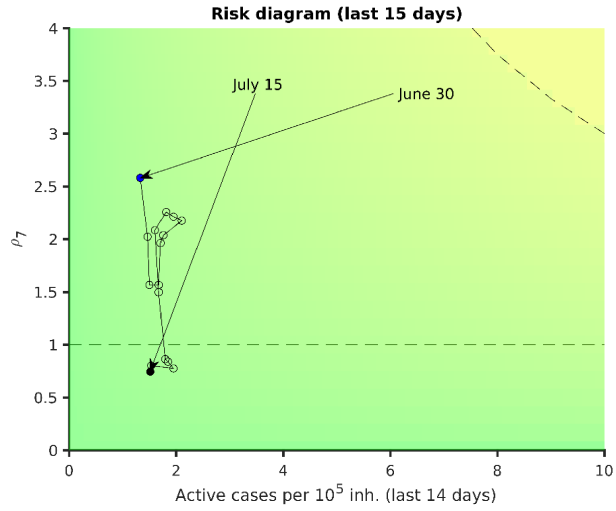




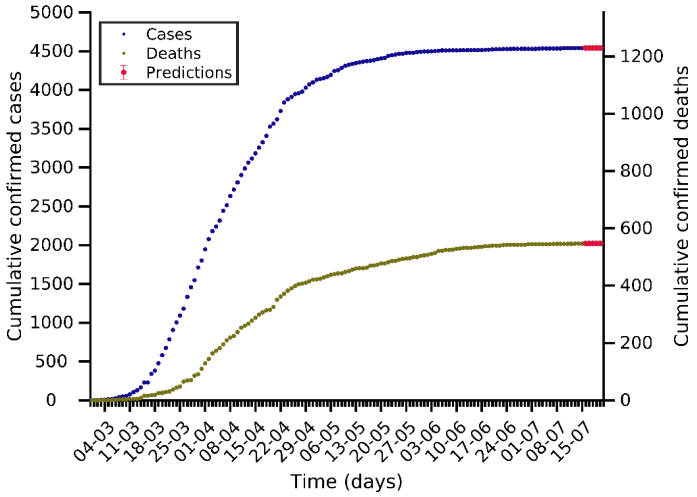


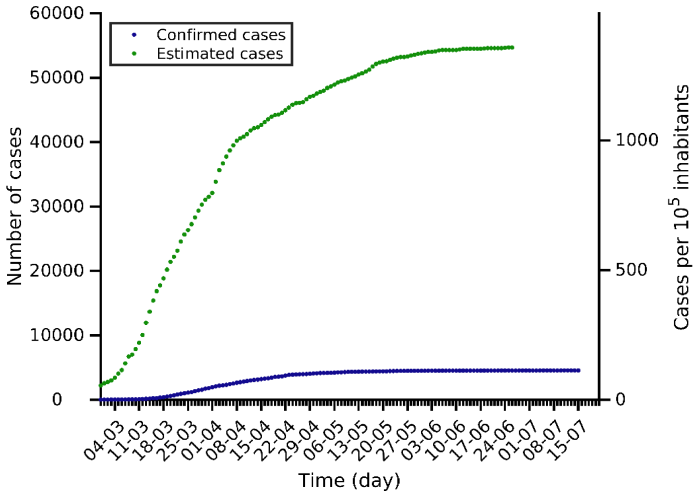


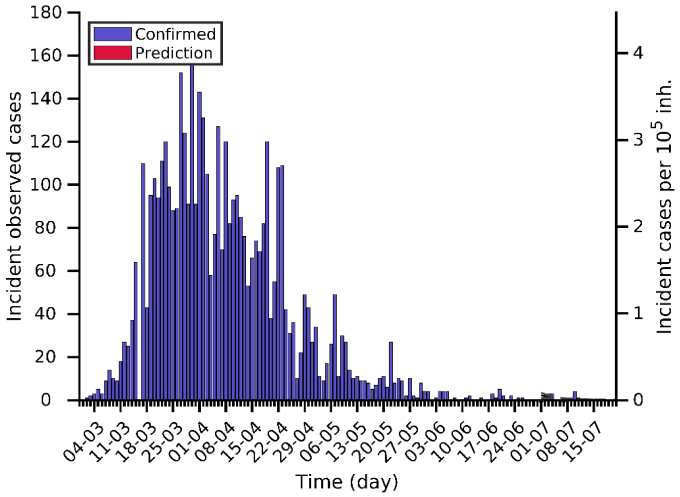


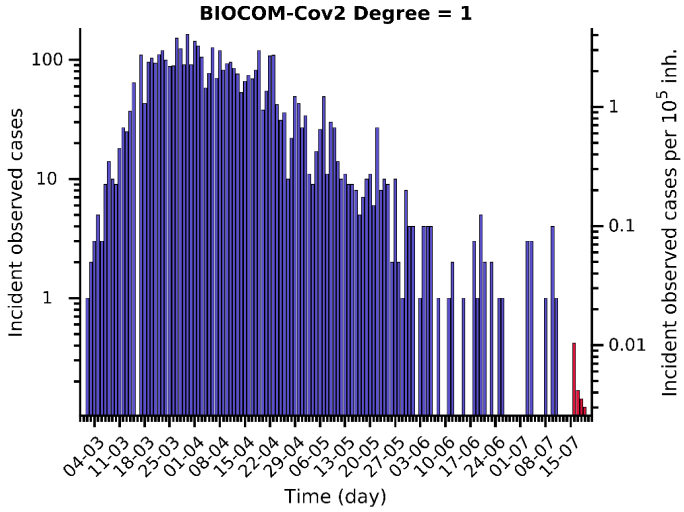


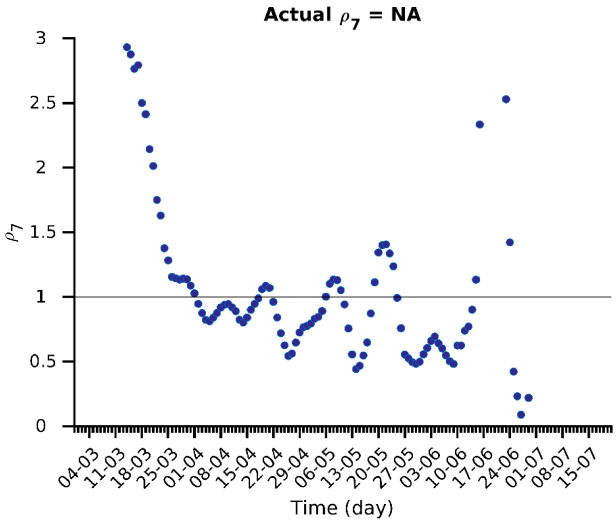
Puglia 15-07-2020. Pop: 4.0M. Cumulative incidence: 113/10⁵

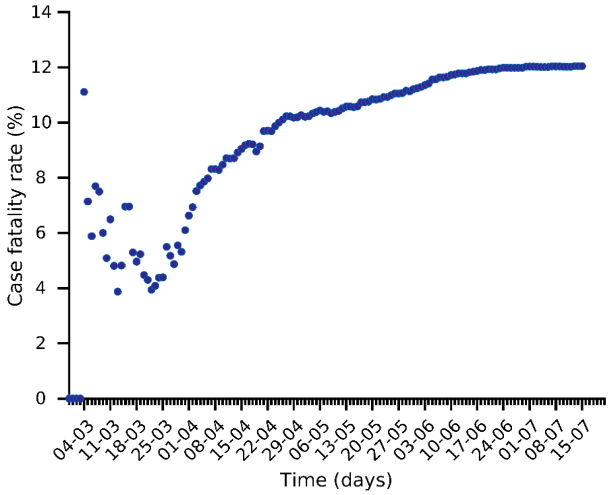


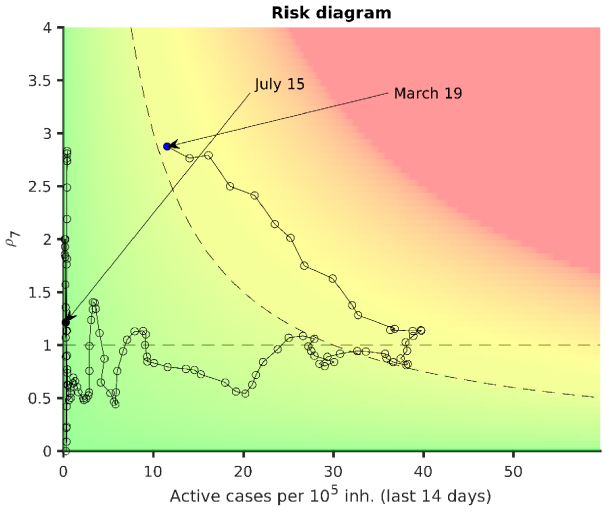


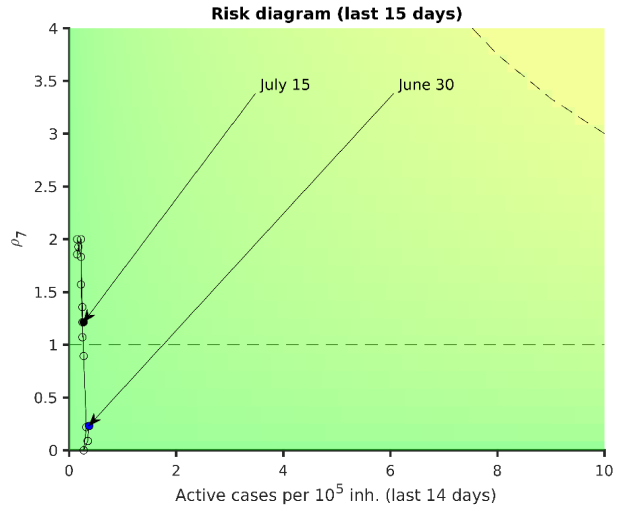




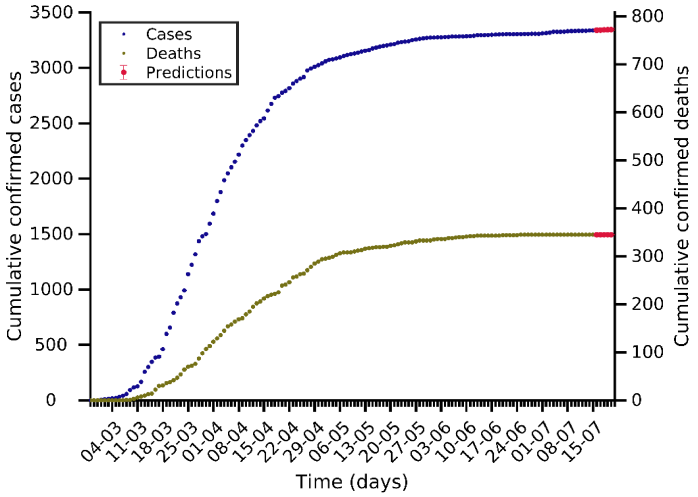


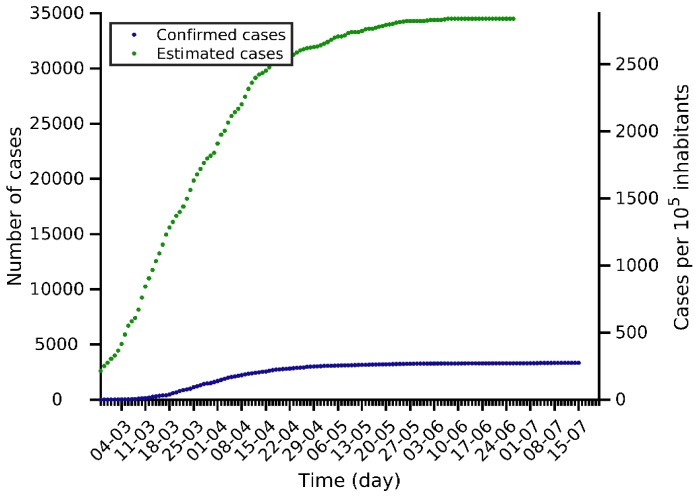


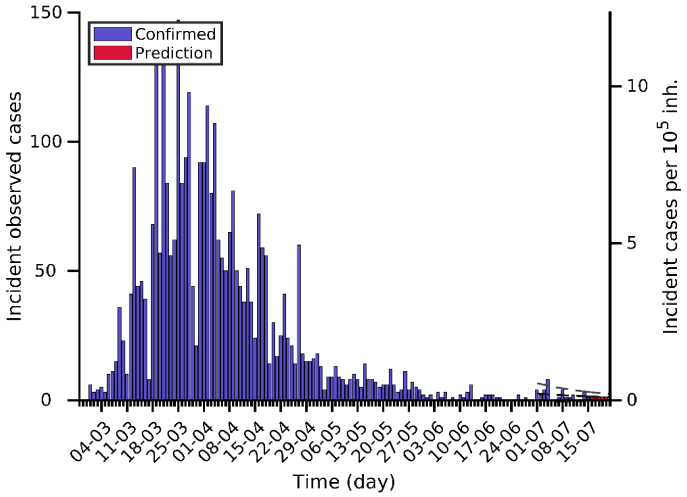


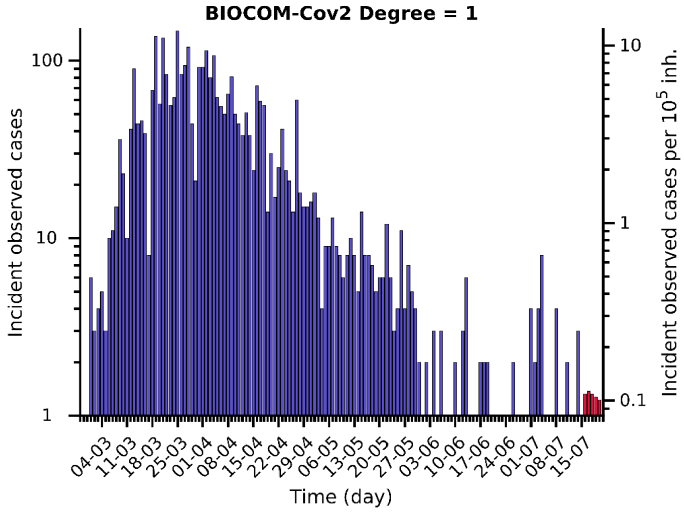


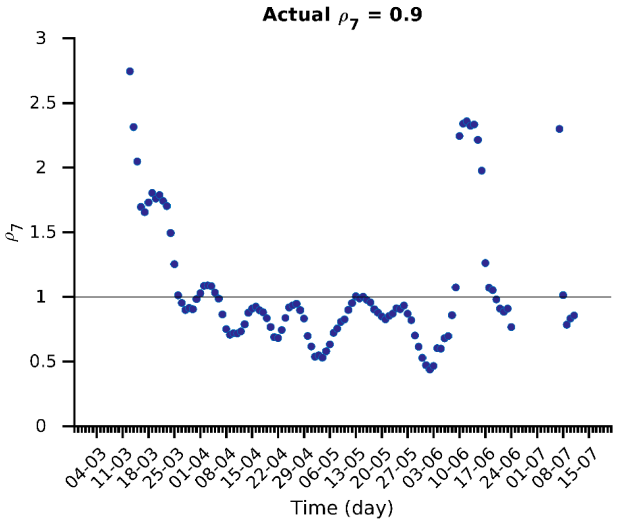
Friuli Venezia Giulia 15-07-2020. Pop: 1.2M. Cumulative incidence: 275/10⁵

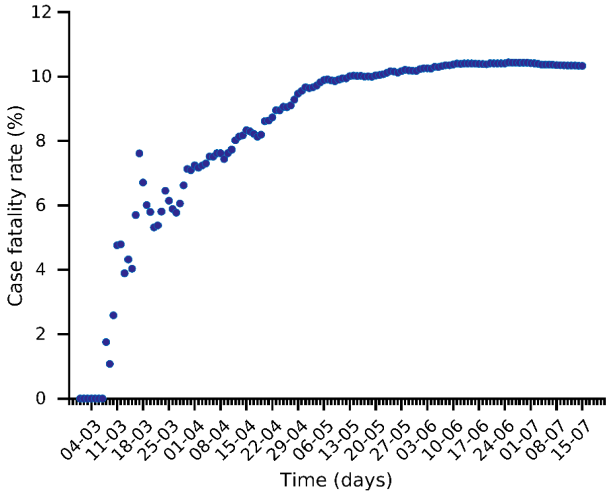


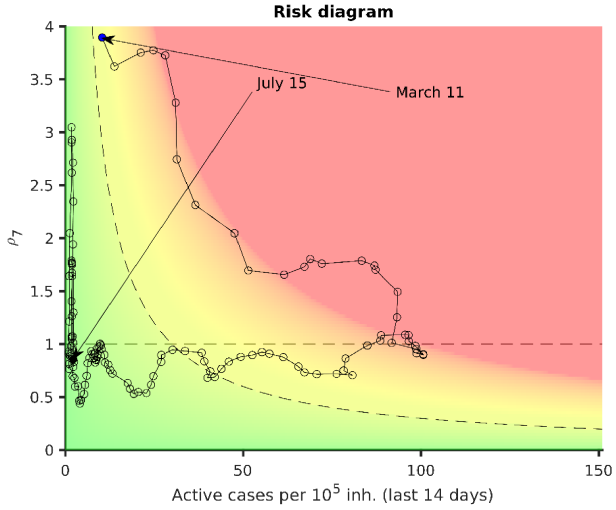


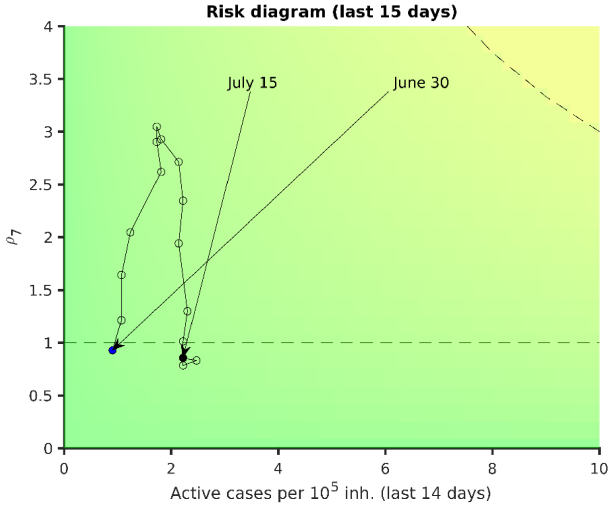




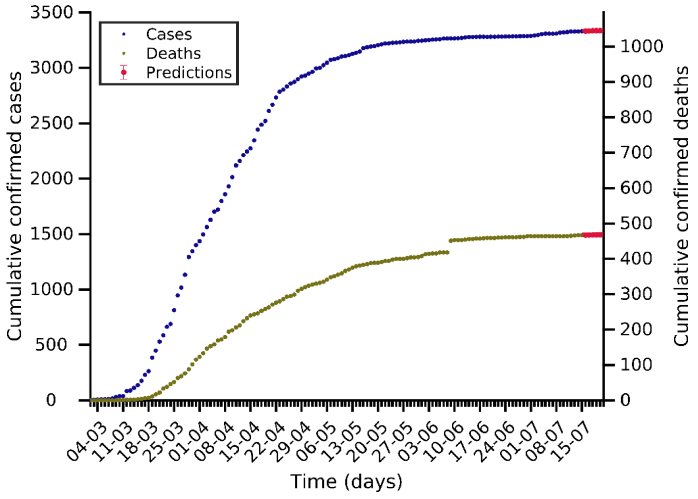


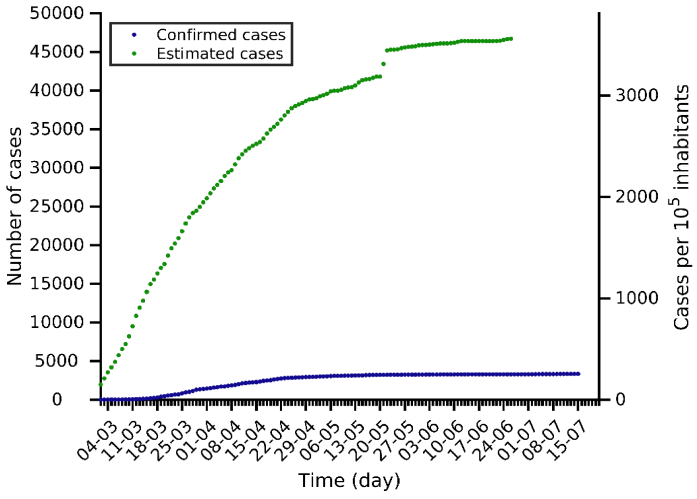


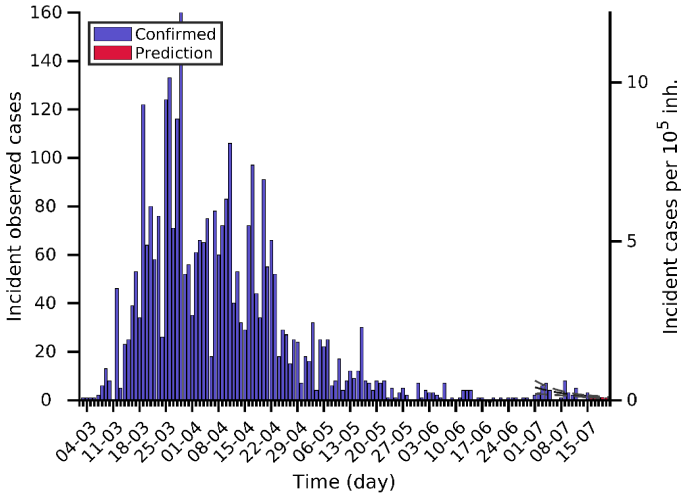


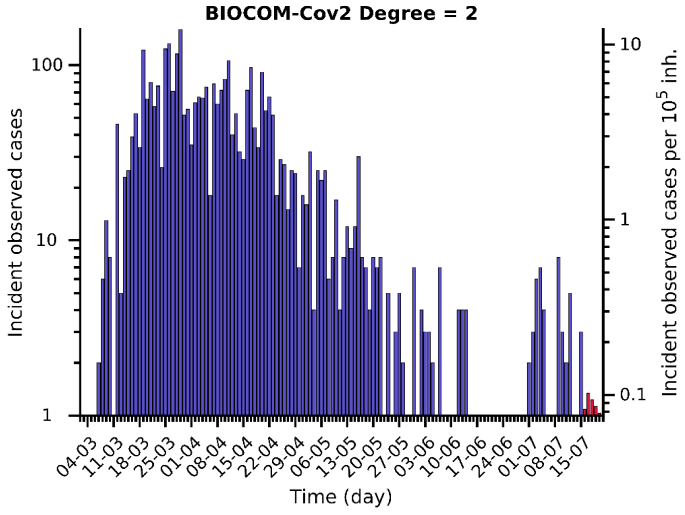


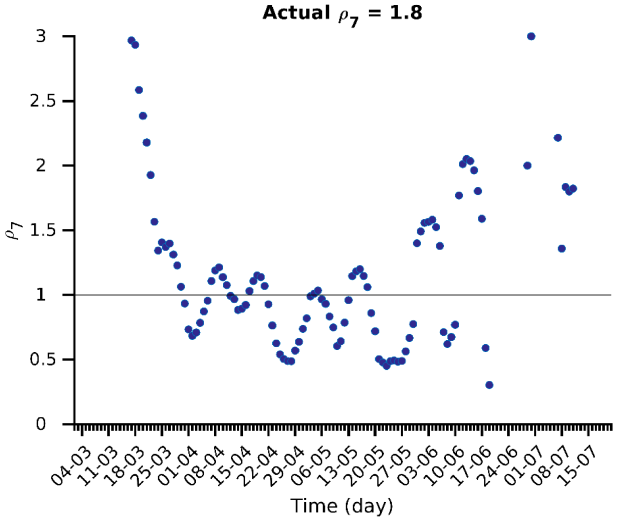
Abruzzo 15-07-2020. Pop: 1.3M. Cumulative incidence: 254/10⁵

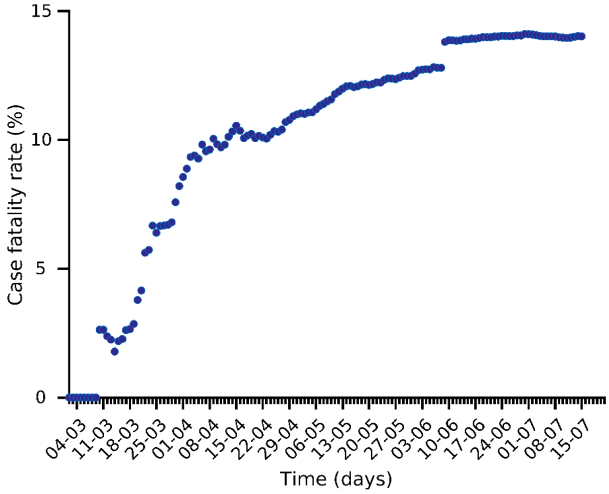


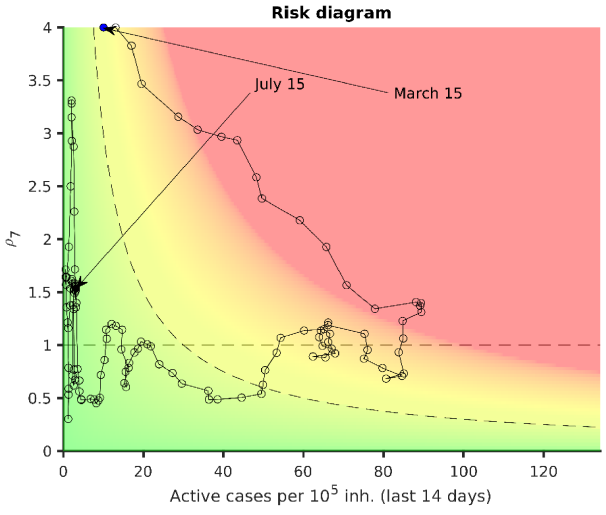


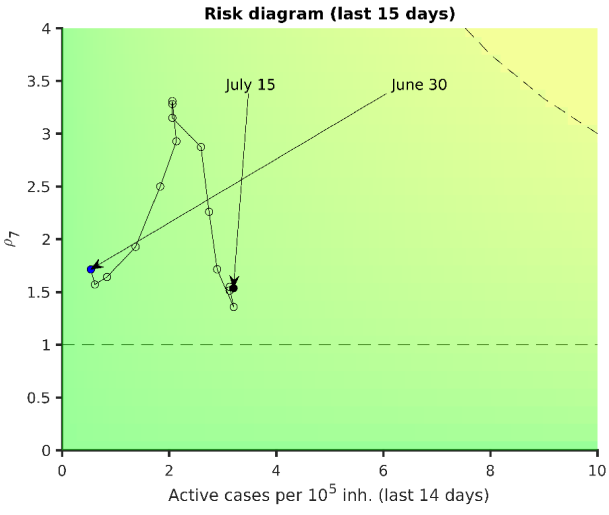




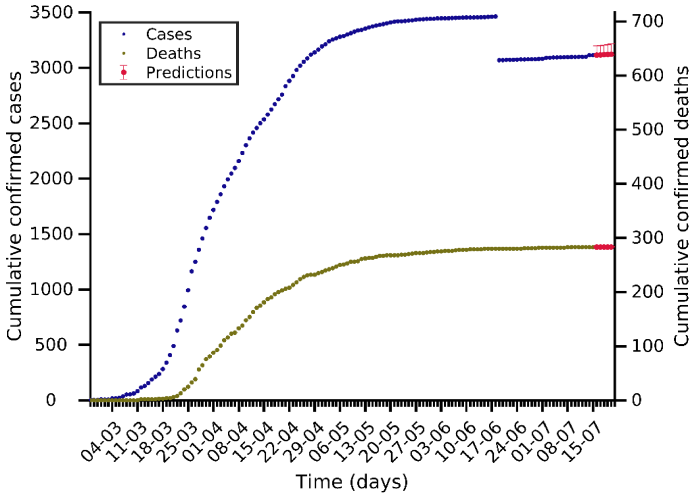


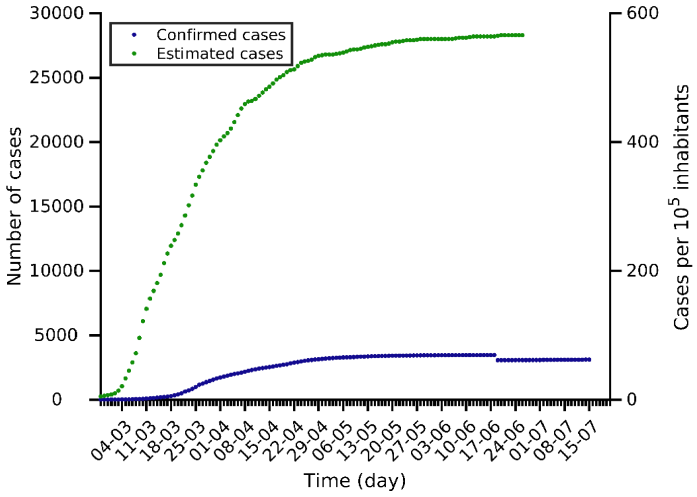


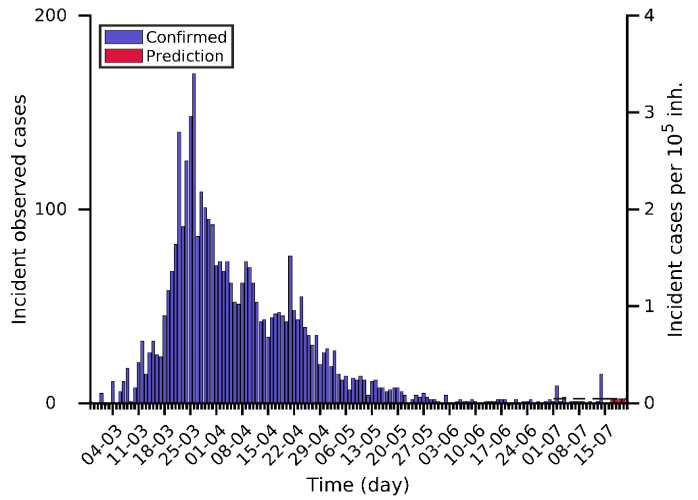


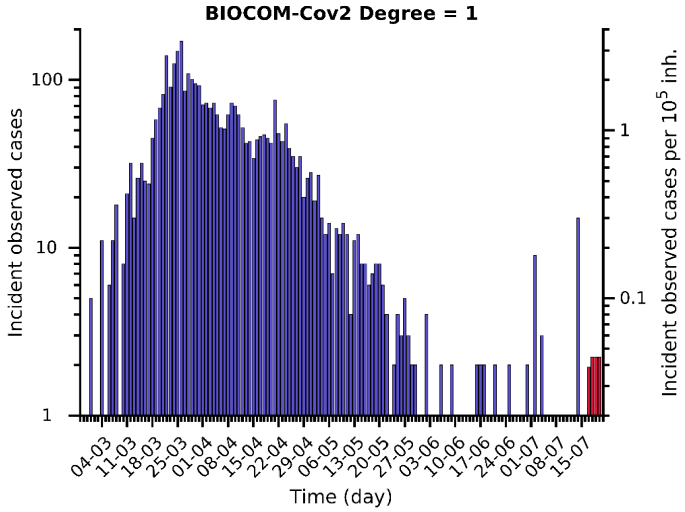


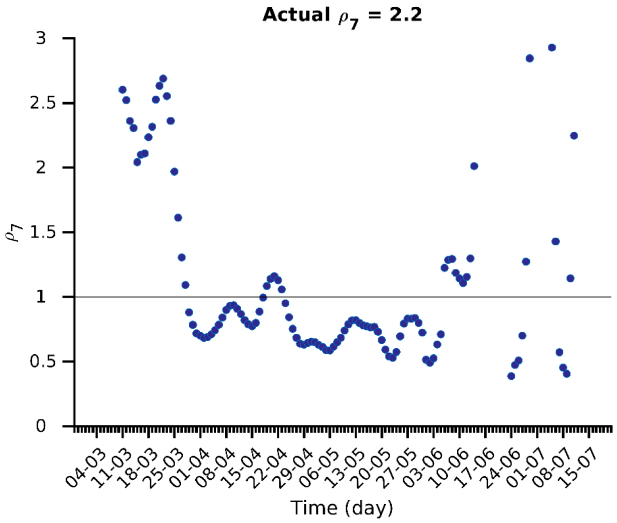
Sicilia 15-07-2020. Pop: 5.0M. Cumulative incidence: 62/10⁵

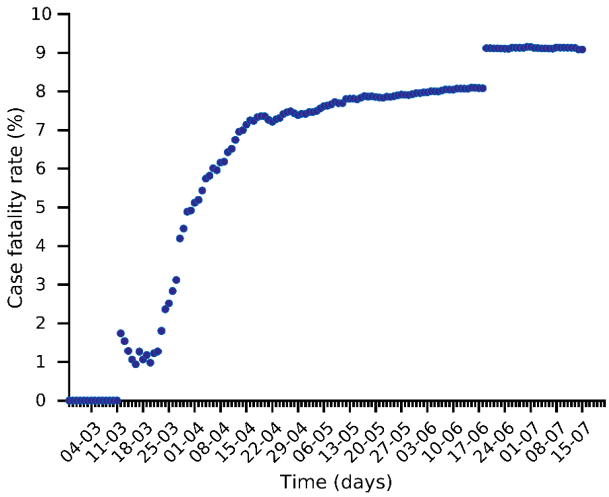


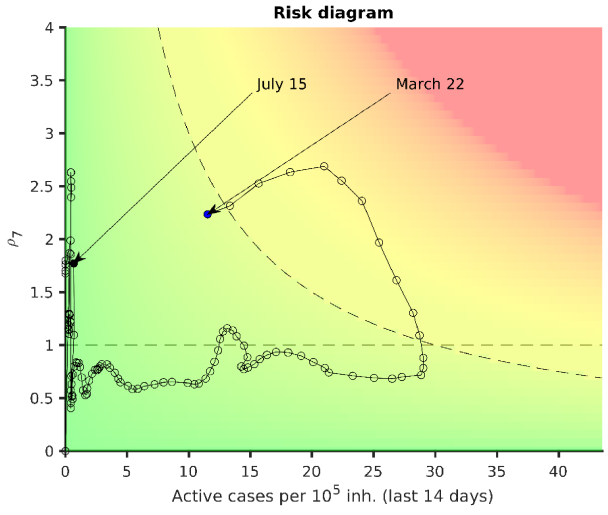


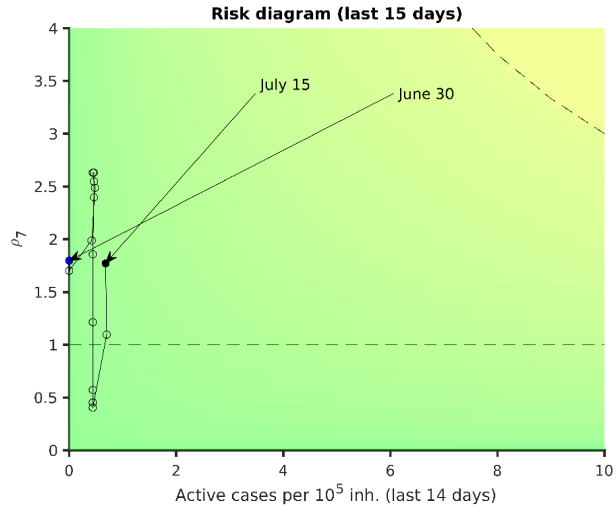




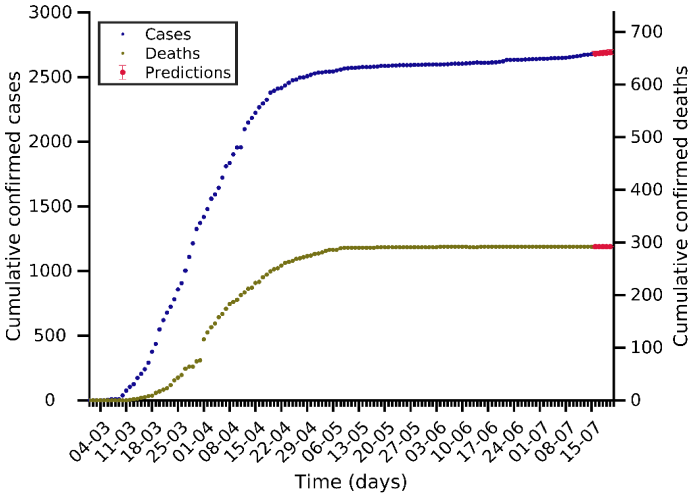


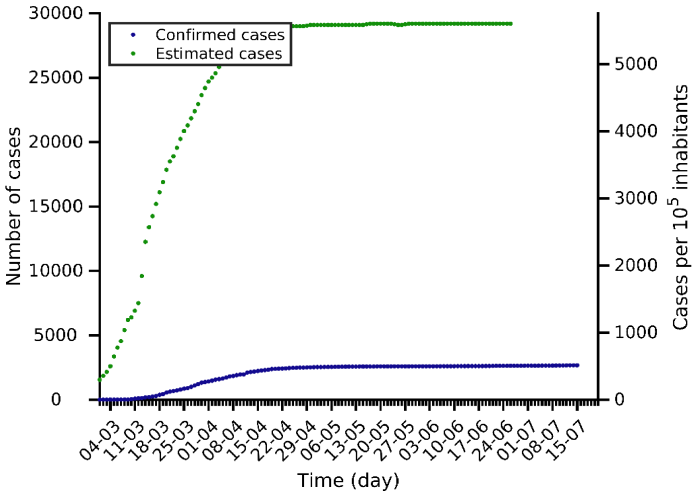


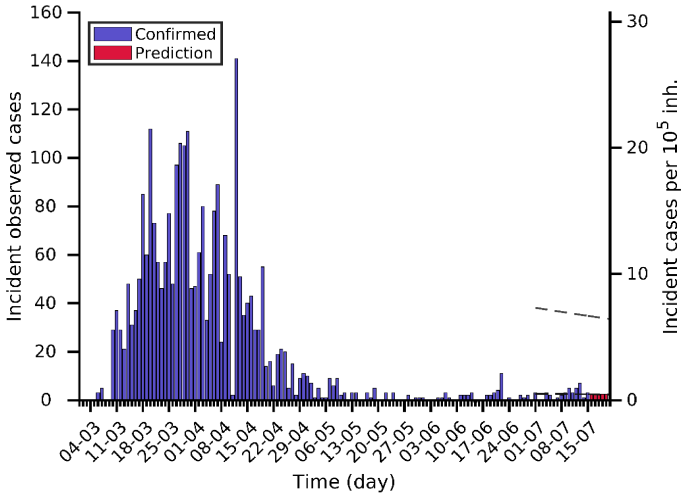


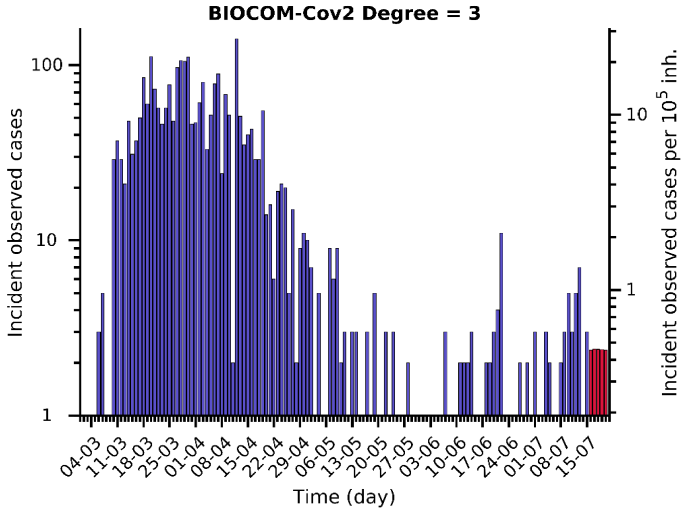


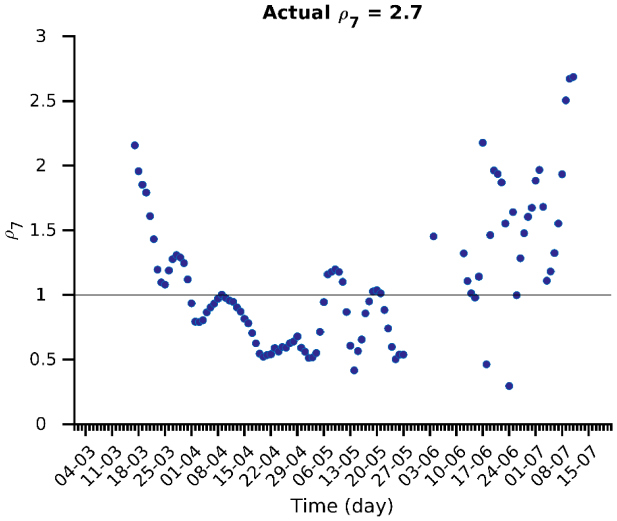
Bolzano 15-07-2020. Pop: 0.5M. Cumulative incidence: 514/10⁵

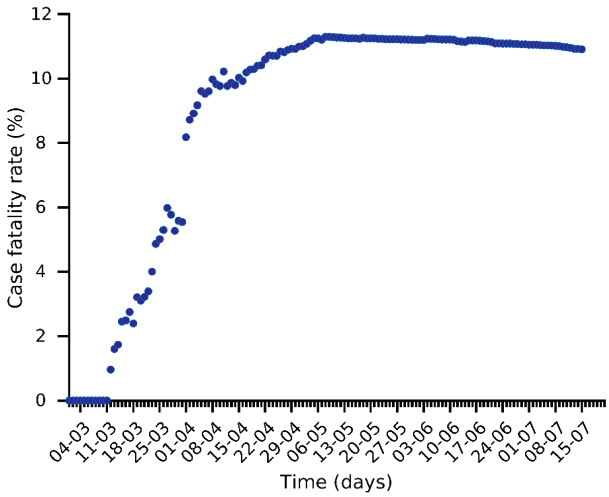


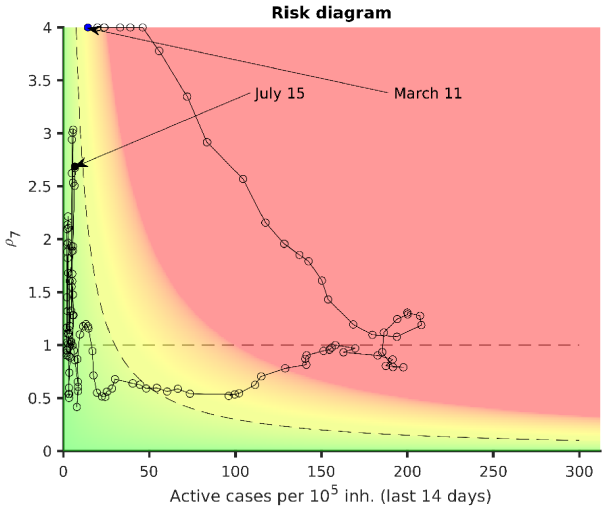


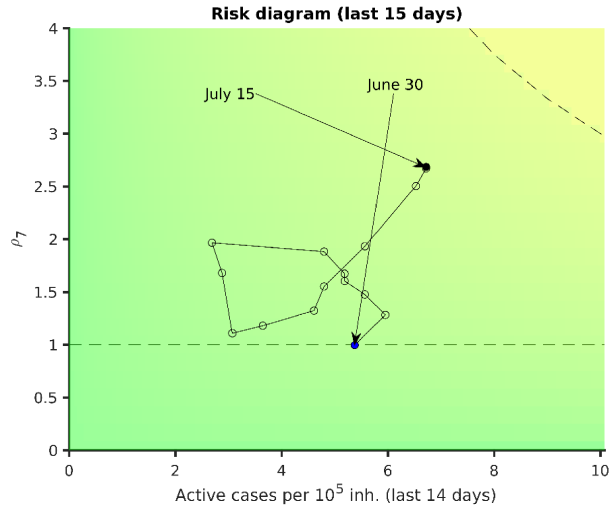




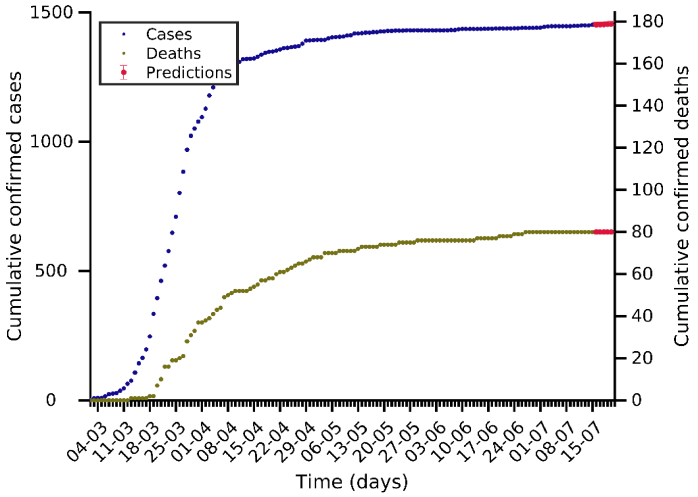


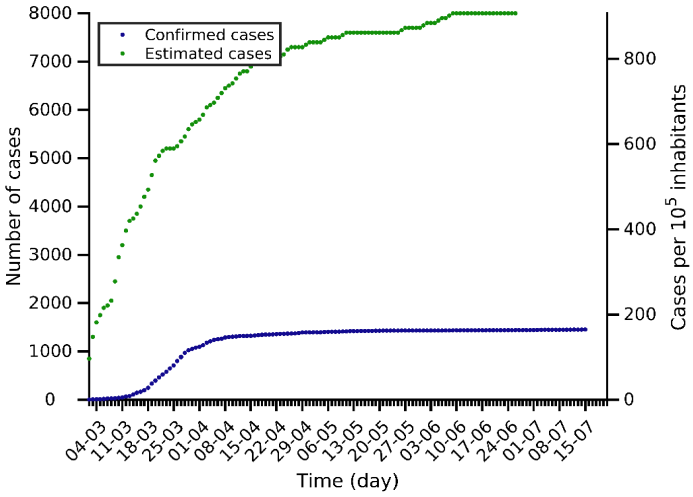


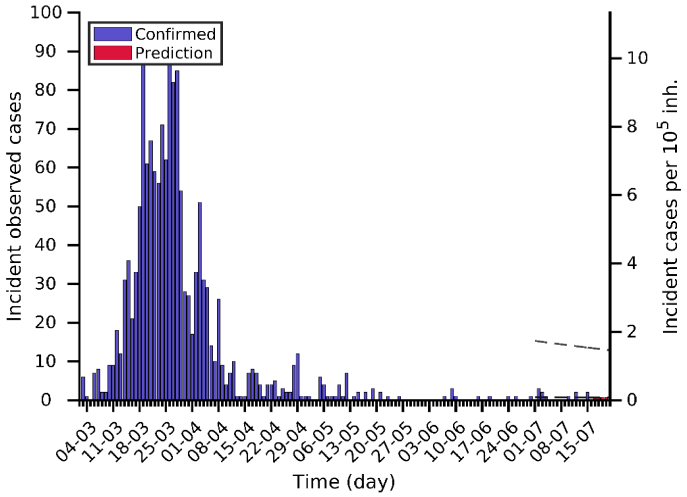


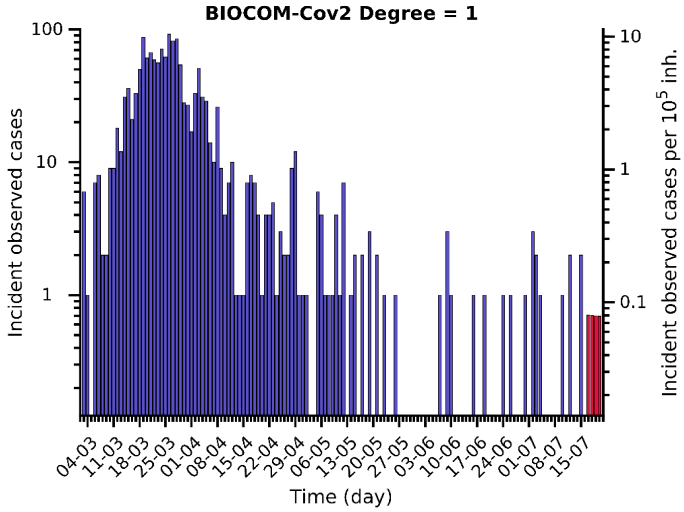


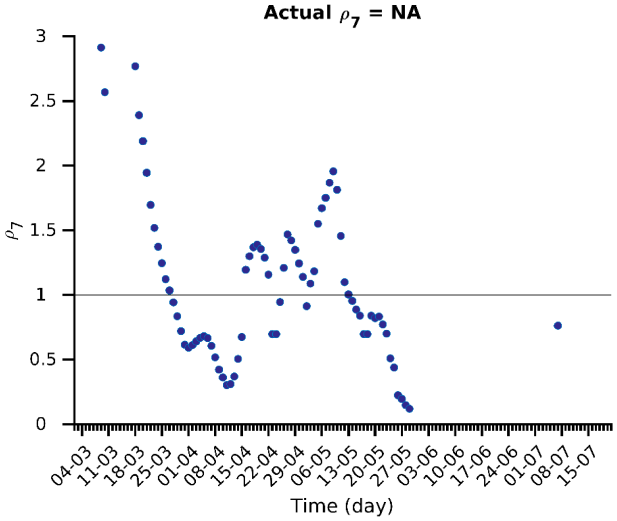
Umbria 15-07-2020. Pop: 0.9M. Cumulative incidence: 165/10⁵

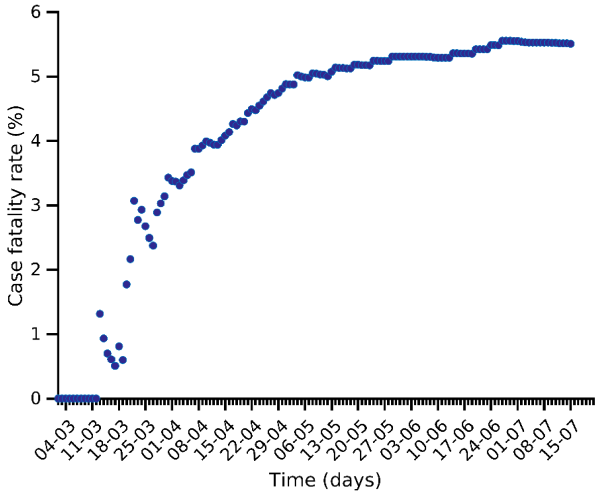


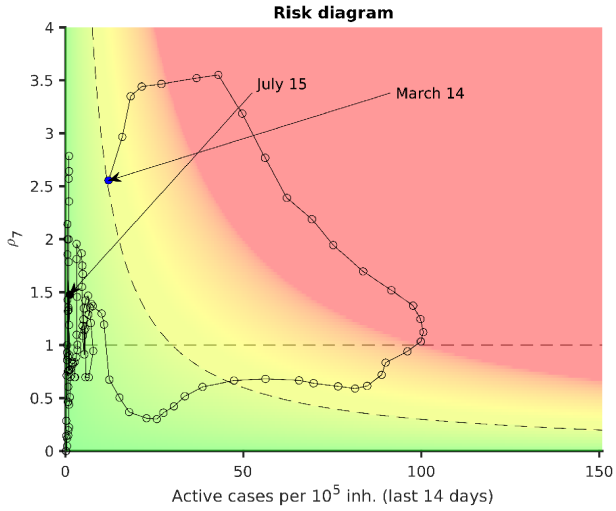


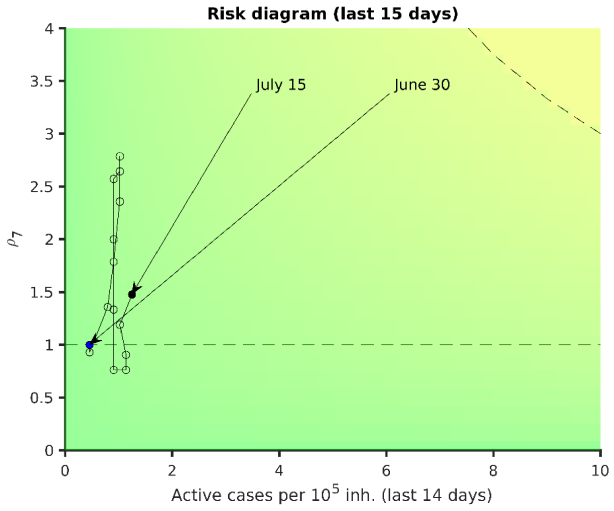




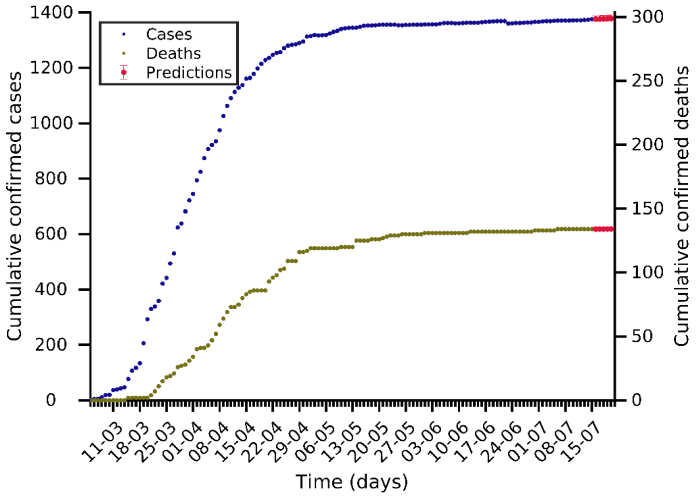


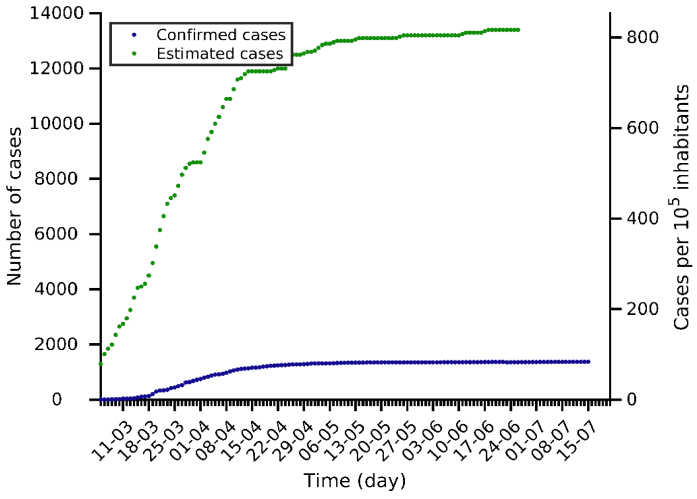


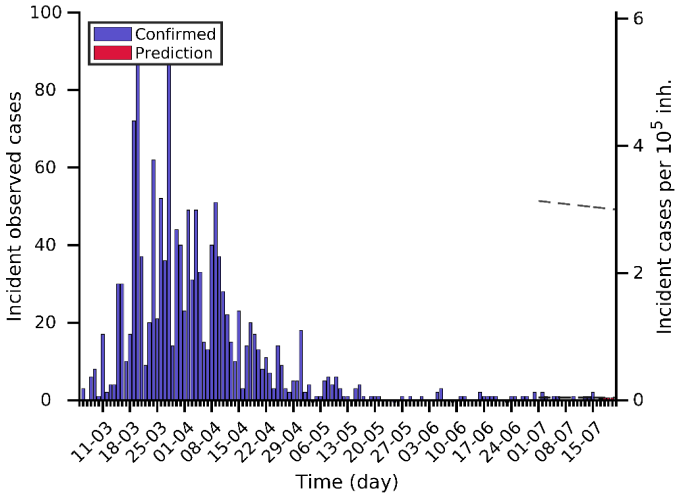


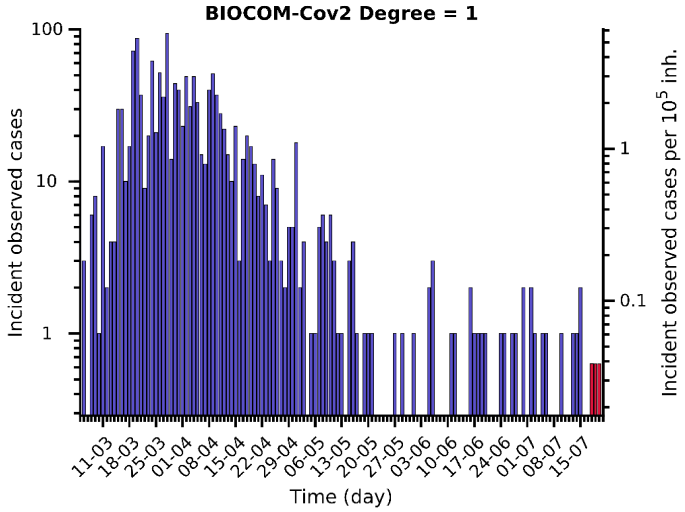


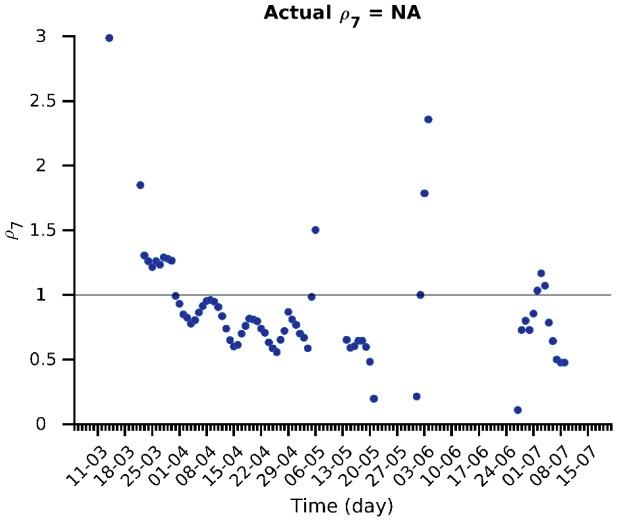
Sardegna 15-07-2020. Pop: 1.6M. Cumulative incidence: 84/10⁵

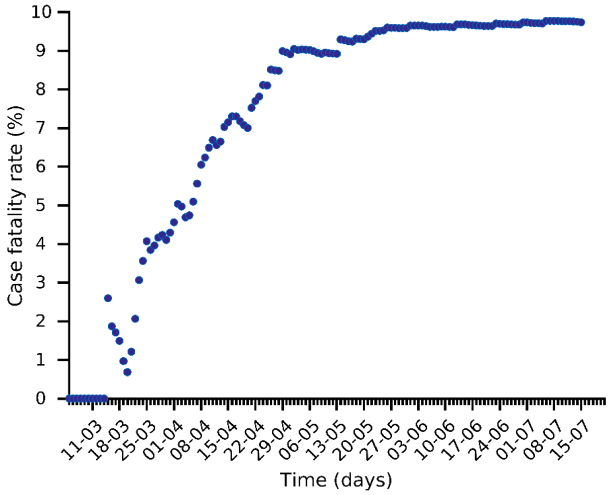


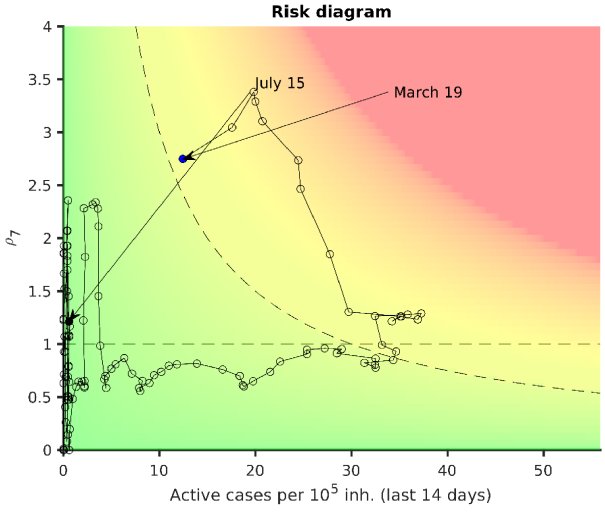


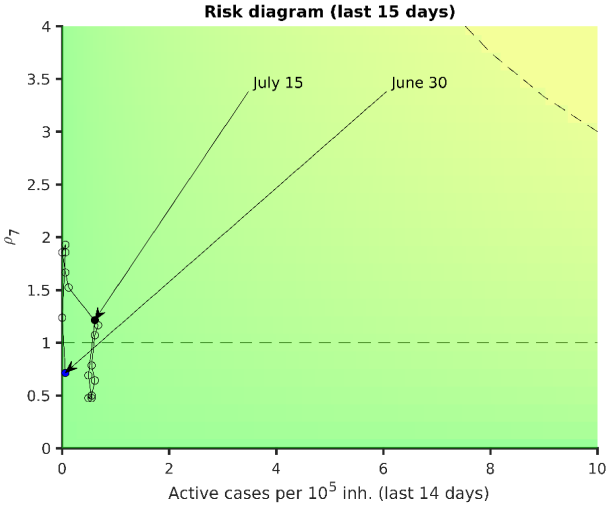




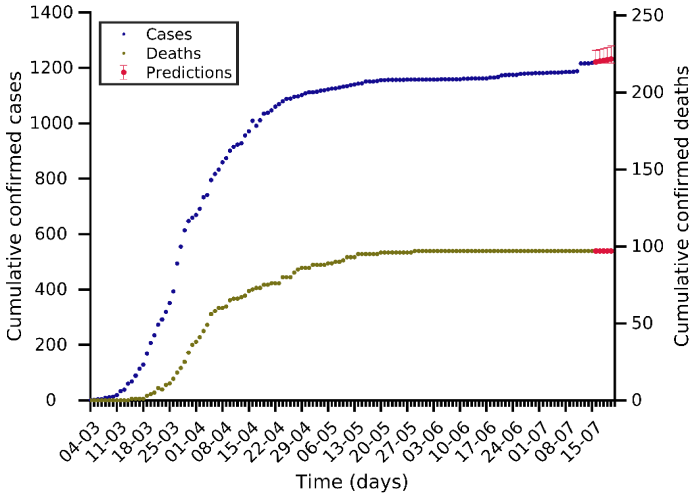


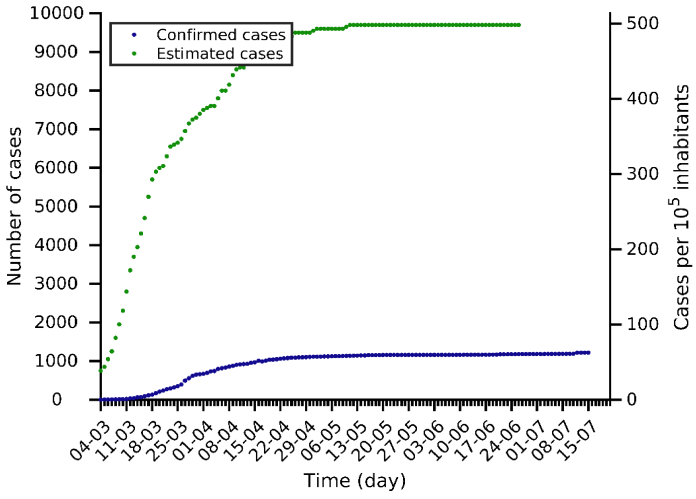


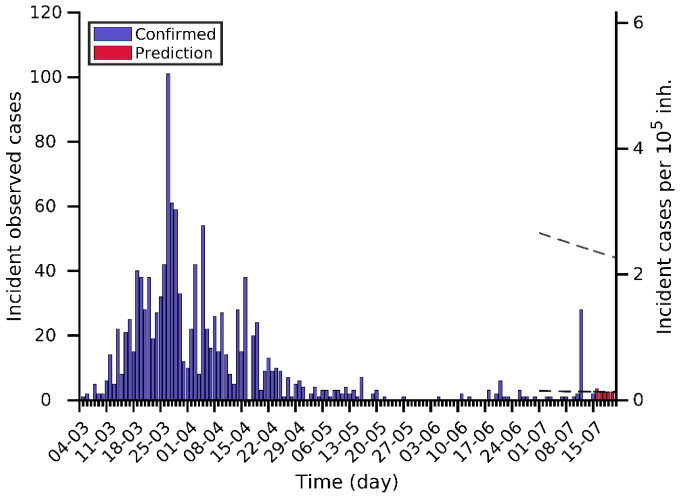


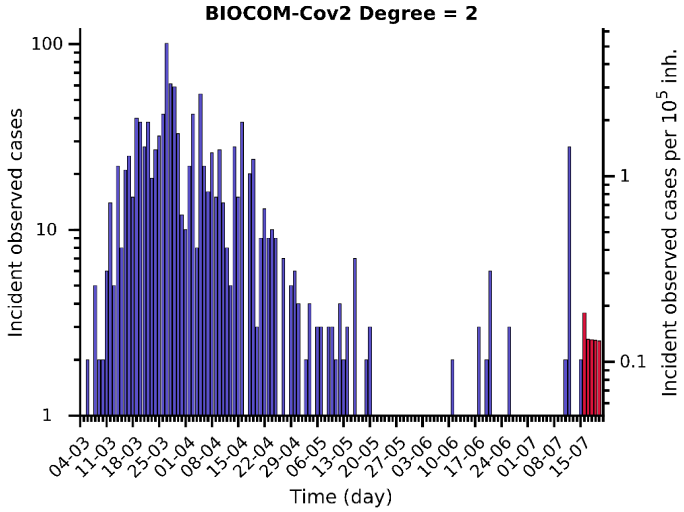


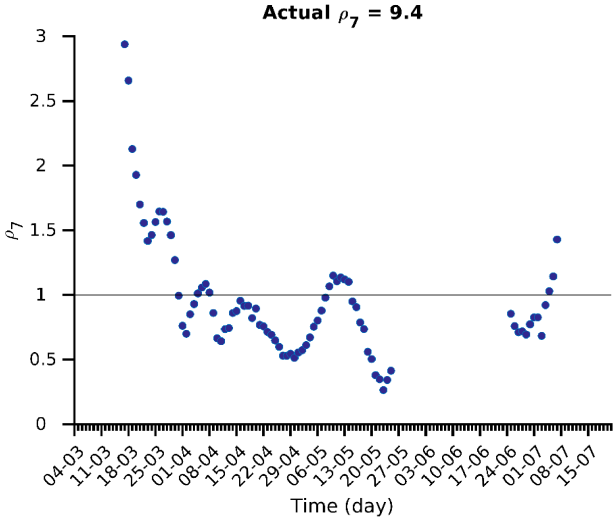
Calabria 15-07-2020. Pop: 1.9M. Cumulative incidence: 63/10^5

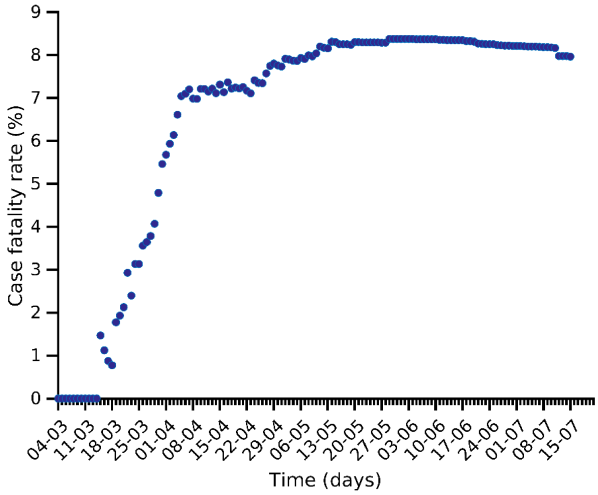


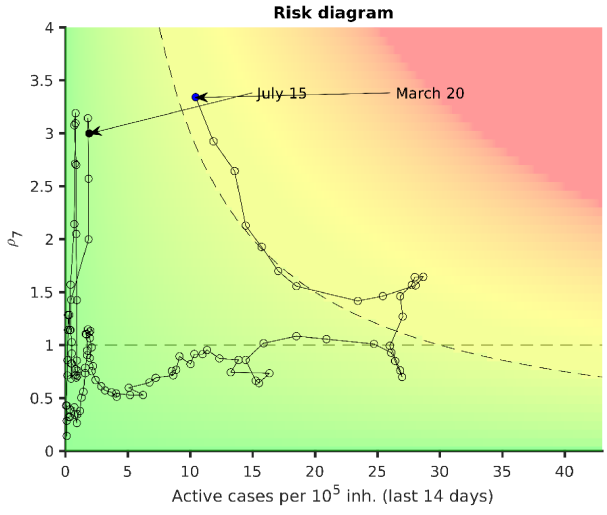


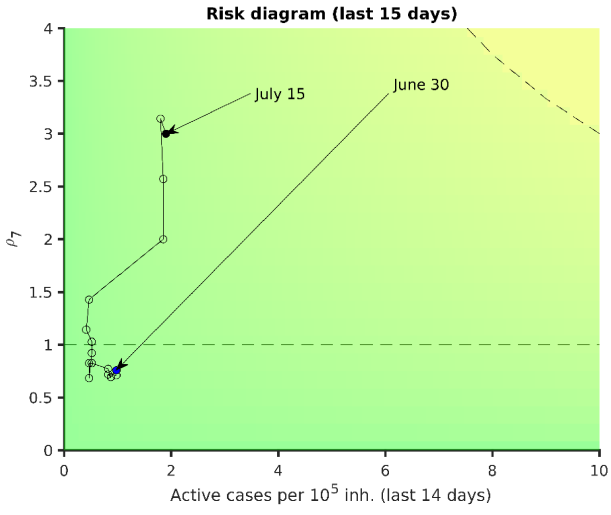




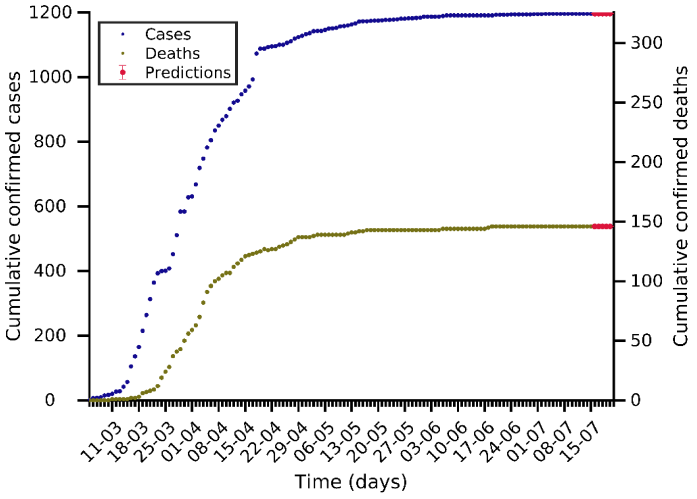


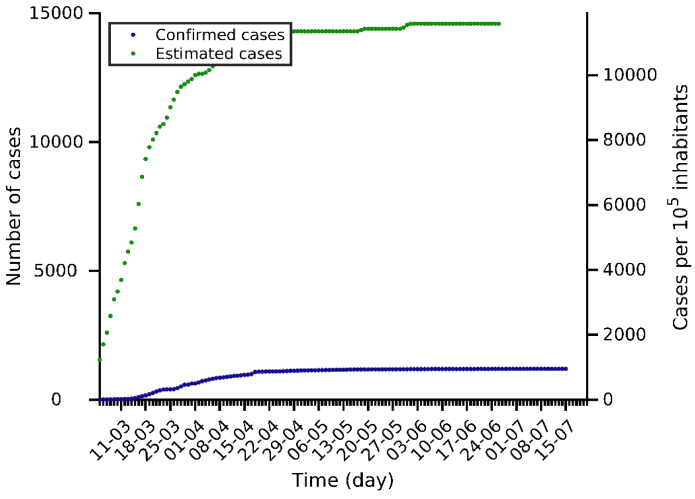


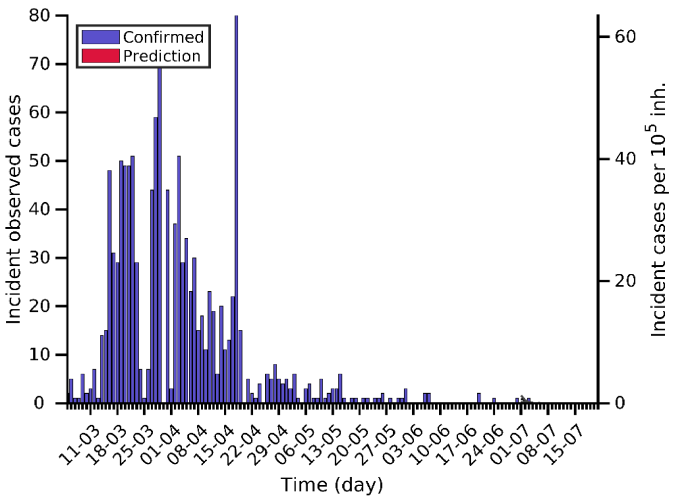


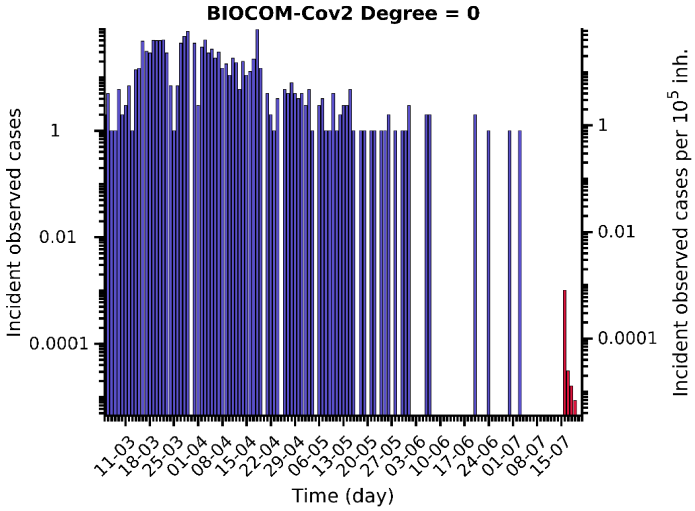


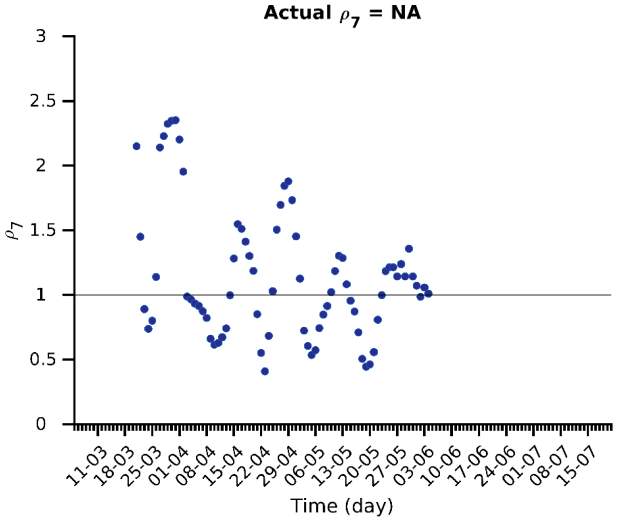
Valle dAosta 15-07-2020. Pop: 0.1M. Cumulative incidence: 949/10⁵

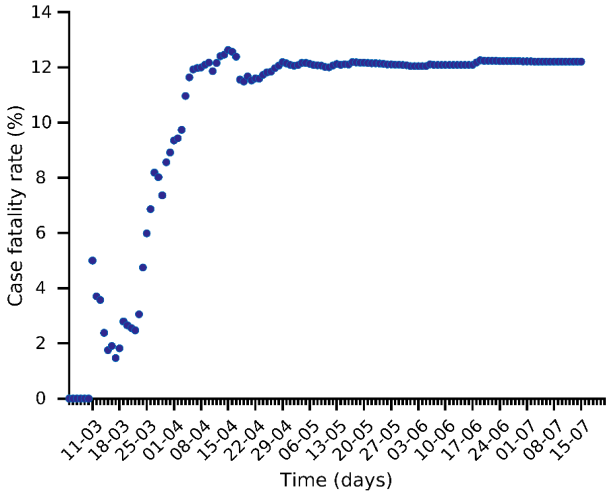


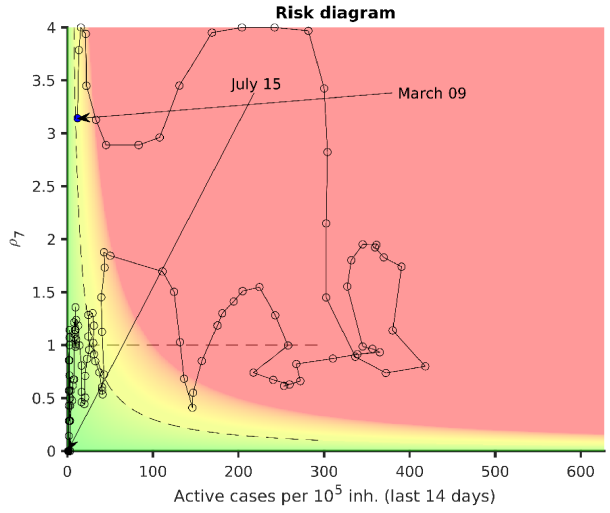


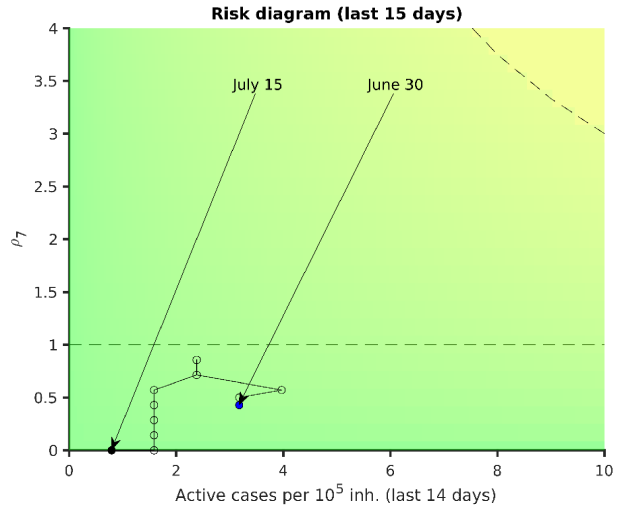




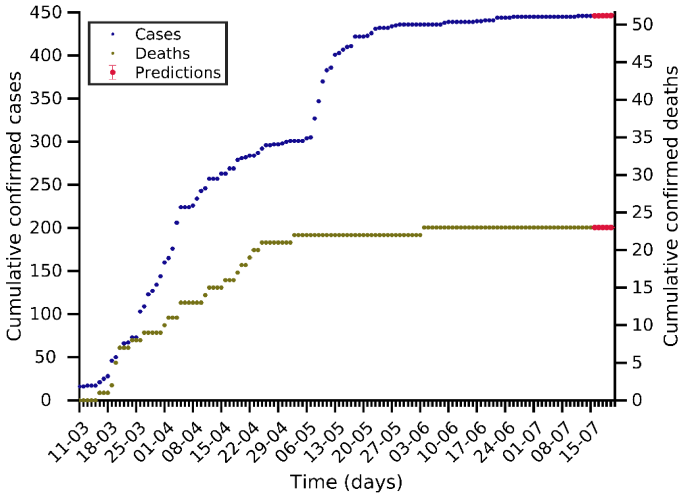


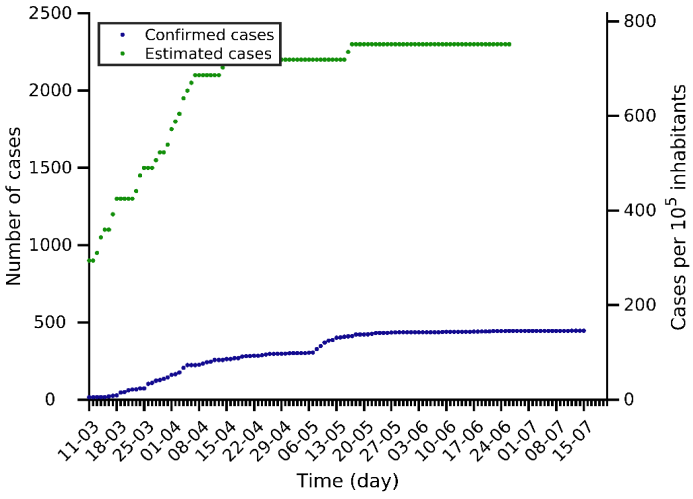


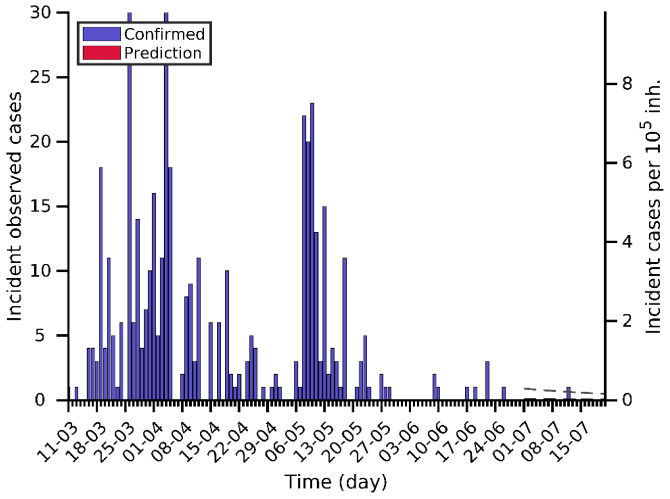


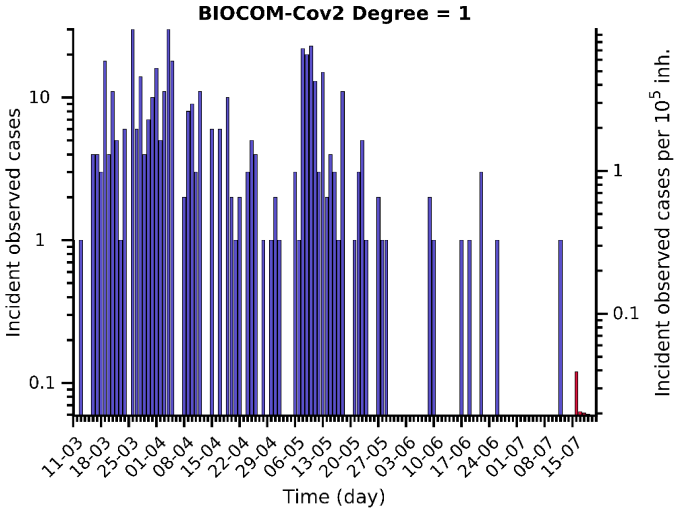


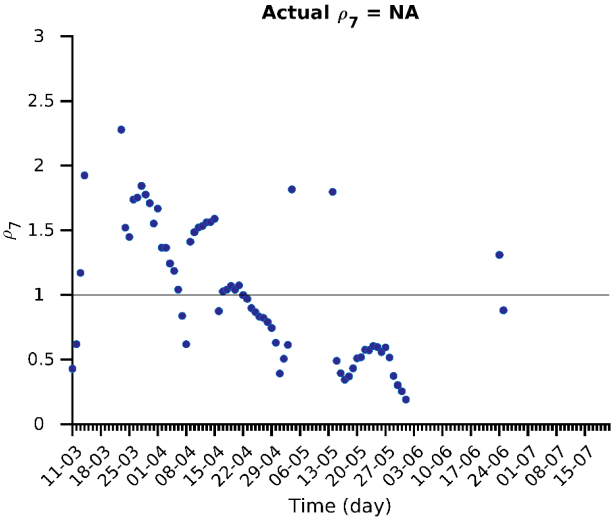
Molise 15-07-2020. Pop: 0.3M. Cumulative incidence: 146/10⁵

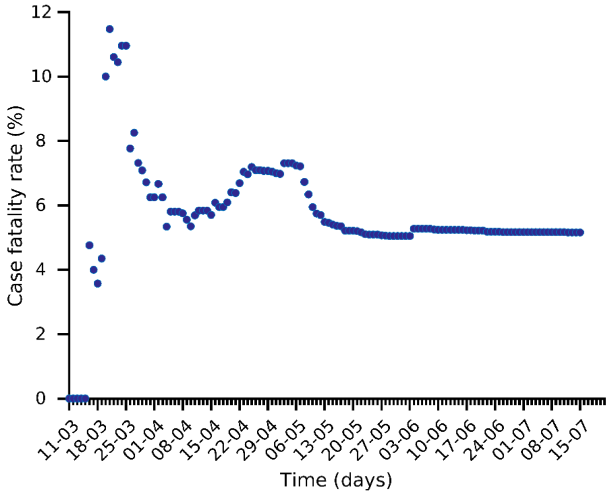


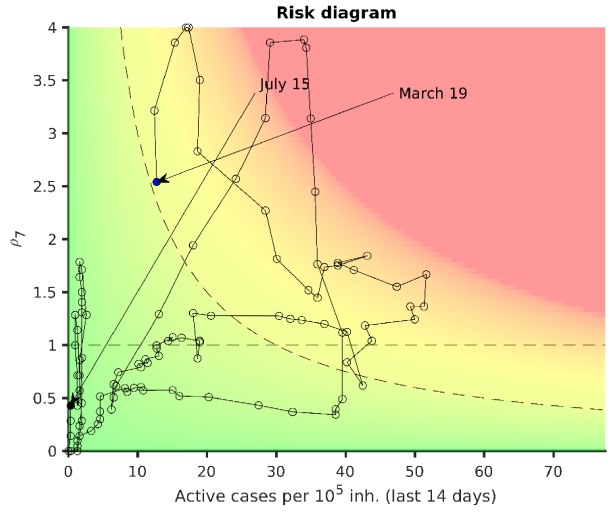


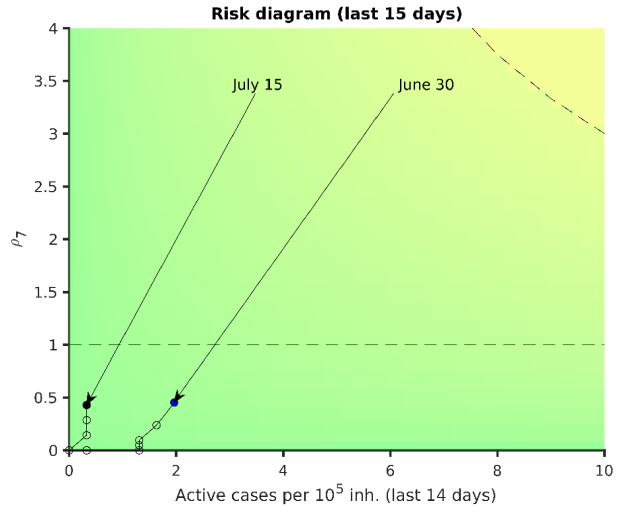




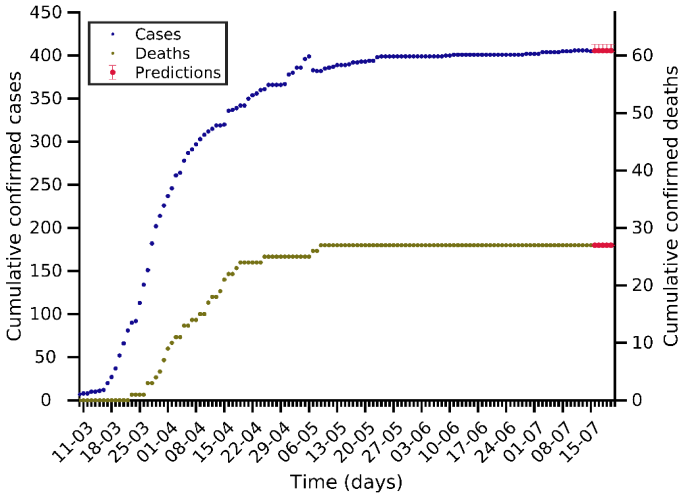


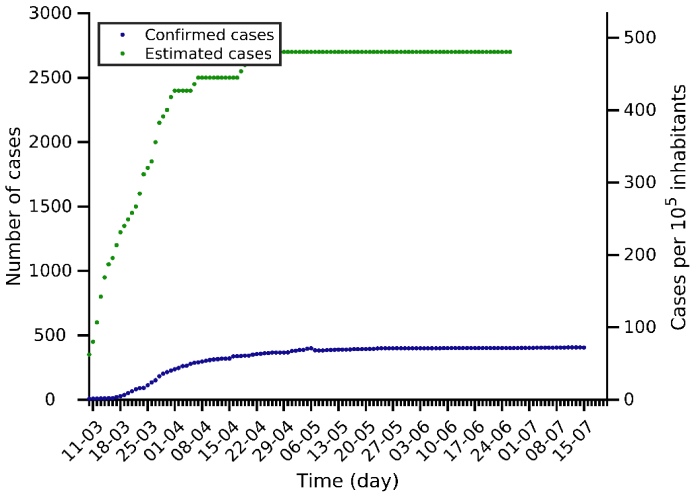


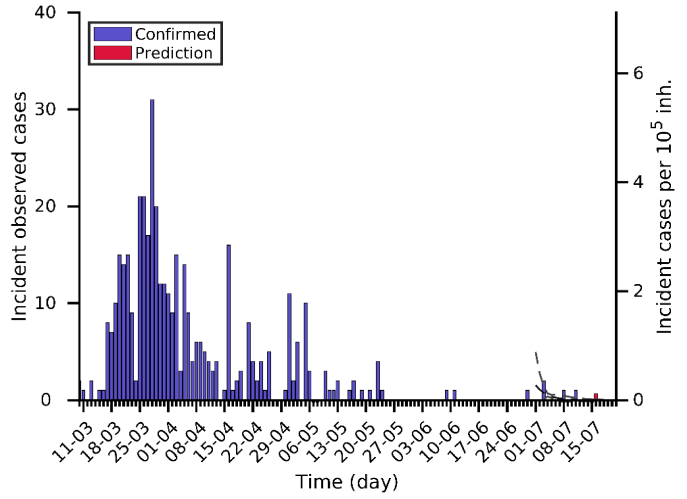


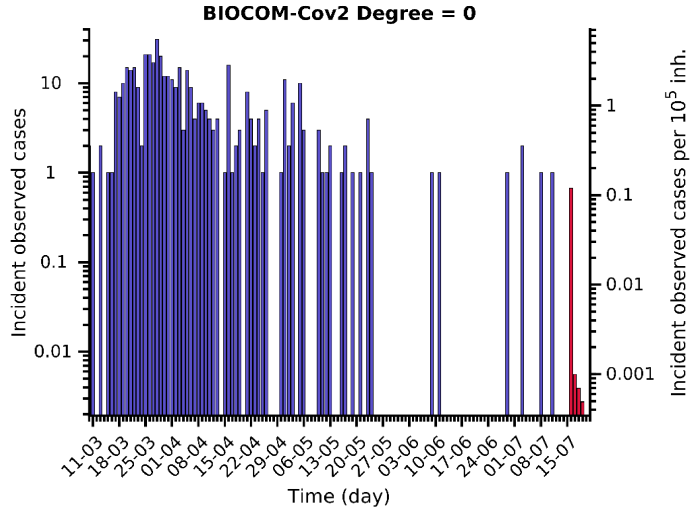


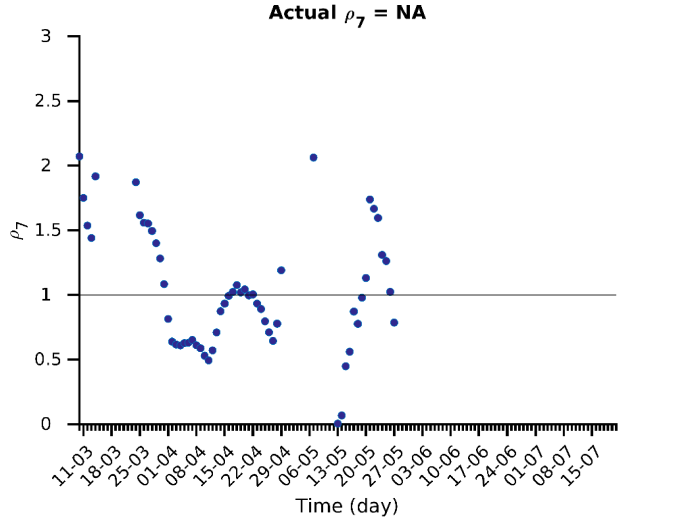
Basilicata 15-07-2020. Pop: 0.6M. Cumulative incidence: 72/10⁵

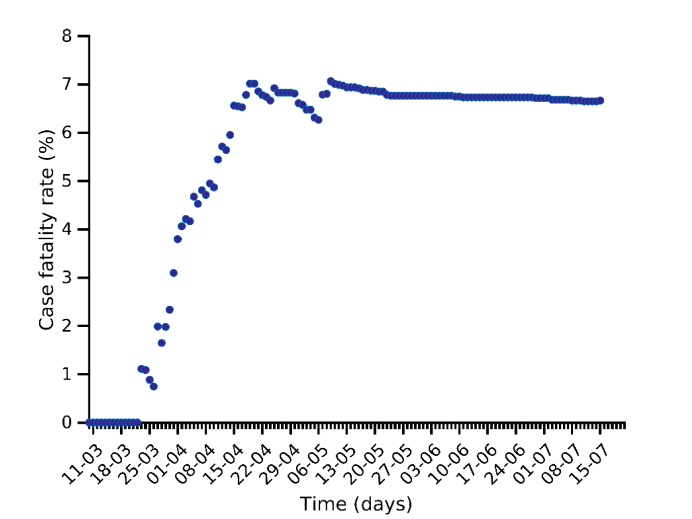


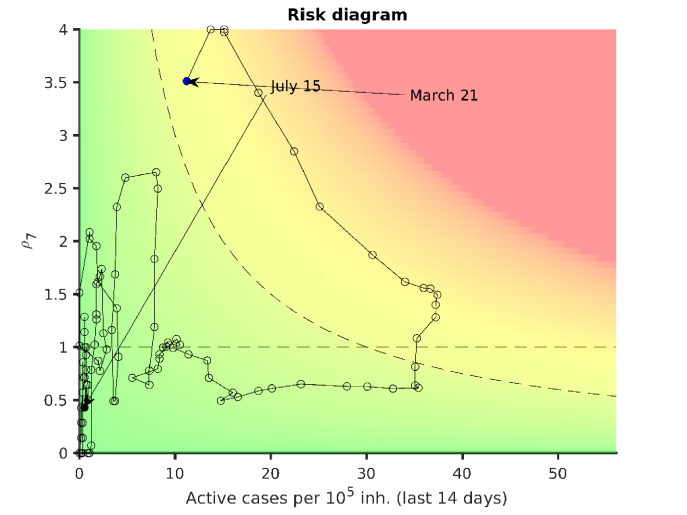


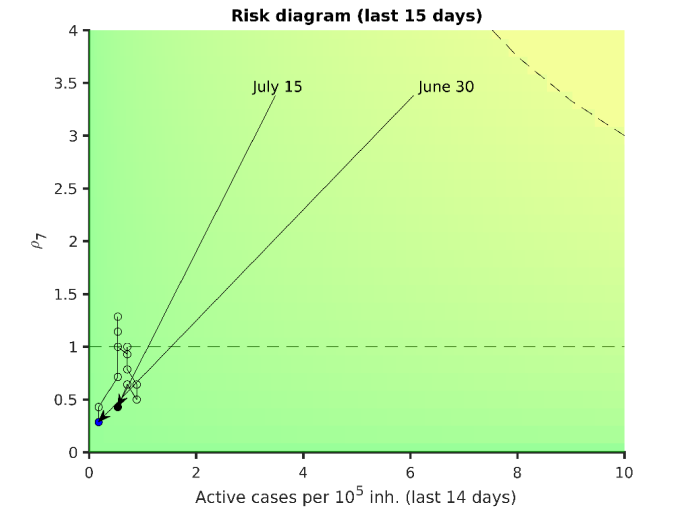












Methods

Methods

(1) Data source

Data are daily obtained from World Health Organization (WHO) surveillance reports[1], from European Centre for Disease Prevention and Control (ECDC)[2] and from Ministerio de Sanidad[3]. These reports are converted into text files that can be processed for subsequent analysis. Daily data comprise, among others: total confirmed cases, total confirmed new cases, total deaths, total new deaths. It must be considered that the report is always providing data from previous day. In the document we use the date at which the datapoint is assumed to belong, i.e., report from 15/03/2020 is giving data from 14/03/2020, the latter being used in the subsequent analysis.

(2) Data processing and plotting

Data are initially processed with Matlab in order to update timeseries, i.e., last datapoints are added to historical sequences. These timeseries are plotted for EU individual countries and for the UE as a whole:

- ✓ Number of cumulated confirmed cases, in blue dots
- ✓ Number of reported new cases
- ✓ Number of cumulated deaths

Then, two indicators are calculated and plotted, too:

- ✓ Number of cumulated deaths divided by the number of cumulated confirmed cases, and reported as a percentage; it is an indirect indicator of the diagnostic level.
- ✓ ρ: this variable is related with the reproduction number, i.e., with the number of new infections caused by a single case. It is evaluated as follows for the day before last report (*t-1*):

$$\rho(t-1) = \frac{N_{new}(t) + N_{new}(t-1) + N_{new}(t-2)}{N_{new}(t-5) + N_{new}(t-6) + N_{new}(t-7)}$$

where $N_{new}(t)$ is the number of new confirmed cases at day t.

(3) Classification of countries according to their status in the epidemic cycle

The evolution of confirmed cases shows a biphasic behaviour:

(I) an initial period where most of the cases are imported;
(II) a subsequent period where most of new cases occur because of local transmission.

Once in the stage II, mathematical models can be used to track evolutions and predict tendencies. Focusing on countries that are on stage II, we classify them in three groups:

- Group A: countries that have reported more than 100 cumulated cases for 10 consecutive days or more;
- Group B: countries that have reported more than 100 cumulated cases for 7 to 9 consecutive days;
- Group C: countries that have reported more than 100 cumulated cases for 4 to 6 days.

[1] https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
[2] https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases
[3] https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov-China/situacionActual.htm https://github.com/datadista/datasets/tree/master/COVID%2019 , https://covid19.isciii.es/

(4) Fitting a mathematical model to data

Previous studies have shown that Gompertz model[4] correctly describes the Covid-19 epidemic in all analysed countries. It is an empirical model that starts with an exponential growth but that gradually decreases its specific growth rate. Therefore, it is adequate for describing an epidemic that is characterized by an initial exponential growth but a progressive decrease in spreading velocity provided that appropriate control measures are applied.

Gompertz model is described by the equation:

$$N(t) = K\, e^{-ln\left(\frac{K}{N_0}\right)\cdot e^{-a\cdot(t-t_0)}}$$

where *N(t)* is the cumulated number of confirmed cases at *t* (in days), and N_0 is the number of cumulated cases the day at day t_0. The model has two parameters:

- ✓ *a* is the velocity at which specific spreading rate is slowing down;
- ✓ *K* is the expected final number of cumulated cases at the end of the epidemic.

This model is fitted to reported cumulated cases of the UE and of countries in stage II that accomplish two criteria: 4 or more consecutive days with more than 100 cumulated cases, and at least one datapoint over 200 cases. Day t_0 is chosen as that one at which *N(t)* overpasses 100 cases. If more than 15 datapoints that accomplish the stated criteria are available, only the last 15 points are used. The fitting is done using Matlab's Curve Fitting package with Nonlinear Least Squares method, which also provides confidence intervals of fitted parameters (*a* and *K*) and the R^2 of the fitting. At the initial stages the dynamics is exponential and *K* cannot be correctly evaluated. In fact, at this stage the most relevant parameter is *a*. Fitted curves are incorporated to plots of cumulative reported cases with a dashed line. Once a new fitting is done, two plots are added to the country report:

- ✓ Evolution of fitted *a* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out;
- ✓ Evolution of fitted *K* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out; if lower error bar indicates a value that is lower than current number of cases, the error bar is truncated.

These plots illustrate the increase in fittings' confidence, as fitted values progressively stabilize around a certain value and error bars get smaller when the number of datapoints increases. In fact, in the case of countries, they are discarded and set as "Not enough data" if $a>0.2\ day^{-1}$, if $K>10^6$ or if the error in K overpasses 10^6.

It is worth to mention that the simplicity of this model and the lack of previous assumptions about the Covid-19 behaviour make it appropriate for universal use, i.e., it can be fitted to any country independently of its socioeconomic context and control strategy. Then, the model is capable of quantifying the observed dynamics in an objective and standard manner and predicting short-term tendencies.

(5) Using the model for predicting short-term tendencies

The model is finally used for a short-term prediction of the evolution of the cumulated number of cases. The predictions increase their reliability with the number of datapoints used in the fitting. Therefore, we consider three levels of prediction, depending on the country:

[4] Madden LV. Quantification of disease progression. Protection Ecology 1980; **2**: 159-176.

- Group A: prediction of expected cumulated cases for the following 3-5 days[5];
- Group B: prediction of expected cumulated cases for the following 2 days;
- Group C: prediction of expected cumulated cases for the following day.

The confidence interval of predictions is assessed with the Matlab function `predint`, with a 99% confidence level. These predictions are shown in the plots as red dots with corresponding error bars, and also gathered in the attached table. For series longer than 9 timepoints, last 3 points are weighted in the fitting so that changes in tendencies are well captured by the model.

(6) Estimating non-diagnosed cases

Lethality of Covid-19 has been estimated at around 1 % for Republic of Korea and the Diamond Princess cruise. Besides, median duration of viral shedding after Covid-19 onset has been estimated at 18.5 days for non-survivors[6] in a retrospective study in Wuhan. These data allow for an estimation of total number of cases, considering that the number of deaths at certain moment should be about 1 % of total cases 18.5 days before. This is valid for estimating cases of countries at stage II, since in stage I the deaths would be mostly due to the incidence at the country from which they were imported. We establish a threshold of 50 reported cases before starting this estimation.

Reported deaths are passed through a moving average filter of 5 points in order to smooth tendencies. Then, the corresponding number of cases is found assuming the 1 % lethality. Finally, these cases are distributed between 18 and 19 days before each one.

[5] At this moment we are testing predictions at 4 days for countries with more than 100 cumulated cases for 13-15 consecutive days, and 5 days for 16 or more days.

[6] Zhou et al., 2020. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The Lancet; March 9, doi: 10.1016/S0140-6736(20)30566-3